UNIVERSIDAD COMPLUTENSE DE MADRID
FACULTAD DE PSICOLOGÍA

TESIS DOCTORAL

Psychological effects and mechanisms of mindfulness and compassion programs: a study using an emotional attentional blink task and network analysis

Efectos y mecanismos psicológicos de los programas basados en mindfulness y compasión: un estudio empleando la tarea de parpadeo atencional emocional y análisis de redes

MEMORIA PARA OPTAR AL GRADO DE DOCTOR

PRESENTADA POR

Pablo Roca Morales

DIRECTORES

Carmelo Vázquez Valverde
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PSYCHOLOGICAL EFFECTS AND MECHANISMS OF MINDFULNESS AND COMPASSION PROGRAMS: A STUDY USING AN EMOTIONAL ATTENTIONAL BLINK TASK AND NETWORK ANALYSIS

Pablo Roca Morales

Dissertation advisors:

- Carmelo Vázquez Valverde
- Richard J. McNally

THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN PSYCHOLOGY

Madrid, 2020

ACKNOWLEDGEMENTS

As a clinical psychologist, I have invited my patients many times to write a 'gratitude letter', a classic positive psychology exercise that prompts individuals to thank those whom they have never properly thanked. They often articulate the complexity of the exercise, finding it difficult to catalyze memories and emotions into concrete words. Ironically, here I am, looking at a blank piece of paper, with a lot of gratitude springing from my heart, but not really knowing where to start.

I would like to express my deep gratitude to my advisor and mentor, Prof. Carmelo Vázquez, for his extraordinary support, expert advice, and immense knowledge. Throughout my life, I have always been lucky enough to have mentors who have inspired and encouraged me: Carmelo, you've been this figure for the last four years of my life. Your enthusiastic passion for science and knowledge is contagious! Without your guidance and persistent help, this dissertation would not have been possible. My sincere thanks also go to my co-advisor, Prof. Richard McNally, who provided me the opportunity to join his team at Harvard University. Your heartfelt laughter and funny stories made me feel at home. Your scientific advice and contributions in the last stretch of my dissertation have been crucial. I cannot imagine better mentors and advisors for my Ph.D.

I would also like to thank the rest of my lab mates and colleagues at Complutense University: Gonzalo, Mentxu, Álvaro, Natalia, Ivan, Irene, Teo, Regi, Covi, Almudena^2, Ines, Teresa, Luz, Alba, Ángela, and Oscar. Thank you for your stimulating discussions and insightful comments, which propelled me to examine my research from different perspectives. I will always remember our adventures in the congresses and all the fun we have had over the years. I would also thank my colleagues at McNally Lab: Payton, Ben, Mike, Shaan, and Melissa; thank you for welcoming me with open arms. Special thanks to Micaela for her help in reviewing and editing the manuscript. I would also like to show my special gratitude to Nirakara Lab, with a special mention to Gustavo and Nazareth. Thank you for letting me be part of your "network:" you have, indeed, been a *high central node* in this dissertation. This project would have been impossible without your precious support and infrastructure. I would also like to thank all the meditation instructors: Agustín, Ana, Gonzalo and Silvia.

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From the bottom of my heart, I'm eternally grateful to my two lifelines: my mama Mercedes and my dear Sara. This thesis is dedicated to you. Thank you, mama, for teaching me the importance of introspection, spirituality, discipline, and so much more that has helped me succeed in life. You were the first to teach me how to meditate, and considering the dissertation topic, that's commendable! Sara, thank you for your lovely care and all of your patience during these very intense academic years. I am excited to see what the future will bring for us. I simply couldn't have done this without you: gracias amiga! To my father Jorge, who instilled in me the love of knowledge and the interest in investigating the human mind. I'm also indebted to Pedro, Mari Paz, Dora and Gema: you have treated me like a son these past few years. To my life-master, my beloved Swami: we are all contingent, but you are necessary.

I am also grateful to all my friends who stood by me during the struggles and the successes. Special thanks to Roberto, Dani and Clara: when I was left alone in Madrid, you became my family. "Mmm… madera", that's all I have to say. My thanks are also extended to Veronica; academic life is better because of people like you. A special thanks to 'La panda' (you're too many people to list!), my deep gratitude for all your support over these years, especially the Villen and Jimenez family. Thanks also to the Sai family, who is always in my heart.

Last but not least, I would like to thank all the research participants for their immense social commitment and generosity in offering their time and effort. I hope I’m not missing anyone, but if you have reached this point and you expected to see your name listed above, please do not feel forgotten: I wrote these lines thinking of you.

For those who have touched my life and soul in any way since I started this travel: ¡muchas gracias!

TABLE OF CONTENTS

INDEX OF TABLES AND FIGURES

Note: The tables and figures of the articles follow an independent numbering.

ABSTRACT

Introduction

Social and scientific interest in meditation effects has increased exponentially over the past three decades (Bernstein et al., 2019). The rising popularity of meditation practices may be best explained by the well-validated standardized formats of the Meditation-Based Programs (MBPs; Creswell, 2017). However, the scope of scientific research has been focused almost exclusively on mindfulness meditation, whereas other forms of meditation have not received the scientific attention they deserve (Dahl & Davidson, 2019), as is the case of compassion meditation (Kirby et al., 2017). Although research on compassion meditation is still scarce, some studies suggest that mindfulness and compassion meditation may yield different psychological effects and mechanisms (Brito-Pons et al., 2018; Fox et al., 2016; Singer & Engert, 2019).

Despite the wide range of research on meditation benefits to date, few studies have attempted to empirically examine the mechanisms of change through which meditation produces its effects (Van Dam et al., 2018). Thus, we still do not know exactly *how* and *why* meditation works. Theoretical and empirical models of meditation have emphasized the central role of attentional control as the entry door for the rest of the mechanisms (Malinowski, 2013; Tang et al., 2015). More specifically, the study of attentional bias towards emotional stimuli is postulated as a key mechanism for understanding the effects of meditation practice on psychological distress and well-being (De Raedt et al., 2012; Garland et al., 2015a; Kiken & Shook, 2012; Vago & Nakamura, 2011). Despite widespread agreement on the need to expand research on underlying mechanisms of change in psychological interventions, the adequacy of standard statistical approaches to analyze such mechanisms is under debate (Hofmann et al., 2020). As an alternative to traditional mediation models (Hayes, 2009), the relationship between the outcomes and mechanisms of change can be also studied using a network approach (Borsboom & Cramer, 2013). The network approach may be particularly informative of structural psychological changes within individuals after participating in a standardized meditation program.

Objectives

The main goal of the present doctoral dissertation was to examine the effects and mechanisms of change of two standardized meditation programs in secular contexts: the Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 2013) and the Compassion Cultivation Training (CCT; Goldin & Jazaieri, 2017). For this purpose, the first objective was to examine whether the practices of mindfulness and compassion meditation modulate early stages of the attentional processing of emotional information. This objective was accomplished by using a variation of the Attentional Blink (AB) paradigm. The second objective was to examine the relative effectiveness and mediators of change in mindfulness and compassion standardized programs by using traditional mediation analysis. The third and final objective was to explore the effects of mindfulness and compassion programs in terms of changes in the structure of relationships between psychological outcomes and mechanisms, using a network analysis approach.

Results

Taken together, the main results reported in this dissertation highlight various positive outcomes and mechanisms underlying the standardized mindfulness and compassion programs. First, both mindfulness and compassion reduced the standard AB deficit after the programs, but more importantly, this AB reduction varied depending on different emotions. Second, regarding the psychological effects and mechanisms of the programs, the results of the second study showed that both mindfulness and compassion programs were equally effective in reducing psychological distress (i.e., stress, anxiety, and depression) and promoting well-being. However, mindfulness and compassion meditation achieved these positive outcomes via different mechanisms of change. Whereas the mindfulness program mainly operated through changes in present-moment awareness variables (such as decentering and body awareness), the compassion program operated through changes in socio-emotional variables (such as common humanity and empathy). Furthermore, we also found that decentering was the most important mechanism explaining the effects of mindfulness and compassion programs. Finally, the network analysis approach provided a complementary view of the complex matrix of interactions between all psychological variables assessed in our meditation programs. There were several interesting features in the mindfulness and compassion networks, especially in regard to nodes related to mindfulness, self-compassion, and emotion regulation. Moreover, centrality and predictability metrics provided new evidence for the common and specific effects of mindfulness and compassion programs, in terms of the structure of relationships between the psychological variables. Finally, although community analyses revealed a meaningful network reorganization after the MBSR, CCT communities remained largely intact after the program.

Discussion

The studies presented in this dissertation contribute to a deeper understanding of the effects and mechanisms of standardized meditation programs, as they overcome some of the major methodological limitations in the field (e.g., small samples, excessive reliance on self-report instruments, standard univariate analysis that may not capture dynamic interactions between variables, lack of methodological rigor and comparison groups). One of the main conclusions to be drawn is that there are some common effects and mechanisms shared by mindfulness and compassion programs, whereas other effects seem to be specific to each type of practice. Furthermore, the AB reductions may suggest that meditation practice might improve early automatic stages of emotional processing, thereby increasing the flexibility of cognitive resources allocation. Clarifying these commonalities and differences would improve the efficacy of MBPs and support the inclusion of meditation practice in broader psychological treatment protocols and in the healthcare system. Finally, the network approach in general, and our 'psychonectome' perspective in particular, are postulated as a novel analytic tool to explore the MBP-induced changes that enables an exploration of structural and dynamic changes in the network of psychological constructs resulting from the meditation programs. We encourage future studies to replicate our results by executing further methodological advancements as, for instance, including a non-meditation control group, introducing longitudinal information to analyze the maintenance of the changes over time, and analyzing the effects of different meditation types and practice settings.

RESUMEN

Introducción

En las últimas tres décadas se ha producido un incremento del interés científico y social sobre los efectos de la práctica de meditación (Bernstein et al., 2019). Una de las razones principales para explicar el aumento de popularidad de la meditación es el formato estandarizado y validado de los denominados Programas Basados en Meditación (MBPs; Creswell, 2017). La investigación científica se ha enfocado casi exclusivamente en la práctica de mindfulness, y otras formas de meditación no han recibido la atención científica que merecen (Dahl & Davidson, 2019), como es el caso de la práctica de compasión (Kirby et al., 2017). Aunque la investigación todavía es escasa, algunos estudios sugieren que la práctica de mindfulness y compasión podrían producir diferentes efectos y mecanismos psicológicos (Brito-Pons et al., 2018; Fox et al., 2016; Singer & Engert, 2019).

A pesar del amplio número de investigaciones sobre los beneficios de la meditación, pocos estudios han tratado de examinar empíricamente los mecanismos de cambio a través de los cuales la meditación produce dichos efectos (Van Dam et al., 2018), y todavía desconocemos con exactitud *cómo* y *porqué* funciona la meditación. Modelos teóricos y empíricos sobre el funcionamiento de la meditación han enfatizado el papel central que desempeña el control atencional como la puerta de entrada para el resto de mecanismos (Malinowski, 2013; Tang et al., 2015). En concreto, el estudio de los sesgos atencionales hacia estímulos emocionales se postula como un mecanismo clave para entender los efectos de la práctica de meditación en el funcionamiento psicológico (De Raedt et al., 2012; Garland et al., 2015a; Kiken & Shook, 2012; Vago & Nakamura, 2011). A pesar del acuerdo generalizado sobre la necesidad de incrementar la investigación sobre los mecanismos de cambio de las intervenciones psicológicas, el procedimiento estadístico para analizar dichos mecanismos es controvertido (Hofmann et al., 2020). Como alternativa a los modelos mediacionales tradicionales (Hayes, 2009), la relación entre los efectos y mecanismos de cambio puede ser estudiada empleando una aproximación en red (Borsboom & Cramer, 2013).

Objetivos

El objetivo principal de la presente tesis fue examinar los efectos y mecanismos de cambio de dos programas estandarizados de meditación en contextos seculares: Mindfulness Basado en la Reducción de Estrés (MBSR; Kabat-Zinn, 2013) y el Entrenamiento en Cultivo de la Compasión (CCT; Goldin & Jazaieri, 2017). El primer objetivo fue examinar si la práctica de mindfulness y compasión modulaba estadios tempranos del procesamiento atencional de la información emocional, empleando para ello una variación del paradigma de Parpadeo Atencional (AB). El siguiente objetivo fue examinar la efectividad relativa y los mediadores de cambio de los programas de mindfulness y compasión empleando análisis mediacionales. Finalmente, exploramos los efectos de los programas de mindfulness y compasión en términos del cambio en la estructura de relaciones entre variables y mecanismos psicológicos, empleando para ello análisis de redes.

Resultados

En conjunto, los resultados principales de la presente tesis doctoral subrayan un amplio número de efectos positivos y mecanismos subyacentes a los programas estandarizados de mindfulness y compasión. Primero, tanto la práctica de mindfulness como de compasión reducen el parpadeo atencional, pero lo que es más importante, dicha reducción varía en función de las diferentes emociones. Segundo, respecto a los efectos y mecanismos psicológicos de los programas, los resultados del segundo estudio mostraron que ambos programas fueron igualmente efectivos reduciendo el malestar psicológico (i.e., estrés, ansiedad y depresión) y promoviendo el bienestar. Sin embargo, los mecanismos de cambio a través de los cuales se alcanzan dichos efectos fueron diferentes. Mientras que el programa de mindfulness parece operar a través de cambios en variables relacionadas con la conciencia del momento presente (como el descentramiento o la conciencia corporal), el programa de compasión alcanza esos mismos efectos a través de cambios en variables socio-emocionales (como la humanidad compartida y la empatía). Además, también encontramos que el descentramiento fue uno de los mecanismos más importantes para explicar los efectos diferenciales de los programas de mindfulness y compasión. Finalmente, los análisis de redes ofrecieron una visión complementaria de la matriz de interacciones complejas entre las variables psicológicas implicadas en los programas de meditación. Se observaron diversas

características interesantes en las redes de mindfulness y compasión, especialmente en los nodos que representaban variables de mindfulness, compasión hacia uno mismo y regulación emocional. Además, los índices de centralidad y predictabilidad ofrecieron nueva evidencia de los efectos comunes y específicos de los programas de mindfulness y compasión, en cuanto a la estructura de relaciones entre las variables psicológicas. Finalmente, aunque el análisis de comunidades reveló una reorganización significativa de la red después del programa MBSR, las comunidades permanecieron prácticamente intactas después del CCT.

Discusión

Los estudios presentados en la presente tesis doctoral contribuyen a una comprensión más profunda de los efectos y mecanismos de los programas estandarizados de meditación, solventando algunas de las principales limitaciones metodológicas en el campo (ej. muestras pequeñas, dependencia excesiva en medidas auto-informadas, análisis univariados, la falta de rigor metodológico y de grupos de comparación, etc.). Una de las principales conclusiones derivadas de los estudios es que existen algunos efectos y mecanismos compartidos por los programas de mindfulness y compasión, mientras que otros parecen ser específicos de cada tipo de práctica. Además, las reducciones en el parpadeo atencional sugieren que la práctica de meditación podría mejorar etapas tempranas del procesamiento emocional. Clarificar las comunalidades y diferencias mejorará la eficacia de los MBPs, así como la inclusión de la práctica de meditación en protocolos de tratamientos psicológicos más amplios y en los sistemas sanitarios. Finalmente, la aproximación en red y del 'psychonectome' se postula como una herramienta analítica novedosa para explorar los cambios estructurales y dinámicos como resultados de los programas de meditación en la red de constructos psicológicos. Esperamos que estudios futuros repliquen nuestros resultados implementando más avances metodológicos, incluyendo un grupo control que no practique meditación, introduciendo información longitudinal para analizar el mantenimiento de los cambios a lo largo del tiempo y analizando los efectos de diferentes tipos de meditación y contextos de la práctica.

ACRONYMS

AB = Attentional Blink

ACT = Acceptance and Commitment Therapy

CBPs = Compassion-Based Programs

CBT = Cognitive Behavioral Therapy

CCARE = Center for Compassion and Altruism Research and Education

CCT = Compassion Cultivation Training

DBT = Dialectical Behavior Therapy

EAB = Emotional Attentional Blink

EBT = Evidence-Based Treatment

ERPs = Event-Related Potentials

ERT = Emotion Regulation Therapy

FA = Focused Attention

HEP = Health Enhancement Program

ITT = Intent-To-Treat

LMM = Liverpool Mindfulness Model

MBCT = Mindfulness-Based Cognitive Therapy

MBPs = Meditation-Based Programs

MBSR = Mindfulness-Based Stress Reduction

MMBI = Mindfulness Meditation–Based Intervention

NIH = National Institute of Health

OM = Open Monitoring

RCI = Reliable Change Index

RCTs = Randomized Control Trials

RSVP = Rapid Serial Visual Presentation

RDoC = Research Domain Criteria initiative

TIDieR = Template for Intervention Description and Replication

PREAMBLE AND OUTLINE OF THE THESIS

'The faculty of voluntarily bringing back a wandering attention, over and over again, is the very root of judgment, character, and will. No one is 'compos sui' if he/she have it not. An education which should improve this faculty would be the education par excellence. But it is easier to define this ideal than to give practical instructions for bringing it about'.

William James. The Principles of Psychology. Chapter XI - Attention (1983).

The illustrious figure of William James has been very present in the last year of my PhD. During my time at Harvard University, from where I write these lines, the first thing I saw when I arrived to the office every morning was a quote from Professor James: *'The community stagnates without the impulse of the individual. The impulse dies away without the sympathy of the community'*. In fact, William James was a crucial piece in the establishing of the Department of Psychology at Harvard University, currently located in a building that bears his name (the slender white William James Hall) and stands behind James' house. In 1890, Professor James wrote the highly influential *Principles of Psychology*, a two-volume synthesis and summary of psychology. Among his many personal stakes, he had a great interest in the study of attention, consciousness and awareness: 'Compared to what we ought to be, we are only half awake' (p. 237, James, 1911. *Memories and studies*). On the other side of the world, in the remote Asia, there were people rigorously training their attention and awareness, reducing the tendency of our mind to wander. Ahead of his time, even Prof. James showed his fascination for the potential of such practices (James, 1907). Nowadays, at the beginning of the second decade of the XXI century, meditation has become a very popular practice to train our minds and promote collective human flourishing around the world (Kabat-Zinn, 2019). Indeed, the practice of meditation has become fully incorporated into the mainstream of behavioral and neurobiological sciences (Van Dam et al., 2018).

If you are reading this thesis and are not familiar with meditation practice, I suggest you try a quick exercise: Close your eyes slowly and try to pay attention to the sensations produced by your breathing in your nostrils. Allow your breath to find its own natural rhythm. Observe and accept your experience in this moment without judgment. You do not need to do anything special; just observe with curiosity and interest all the sensations produced by each inhale and exhale; how the air travels down to your lungs and causes your belly to expand. When you feel ready, you can open your eyes again and return, fully awake, to read this dissertation. I encourage you to maintain this attitude of acceptance while you read the studies presented below.

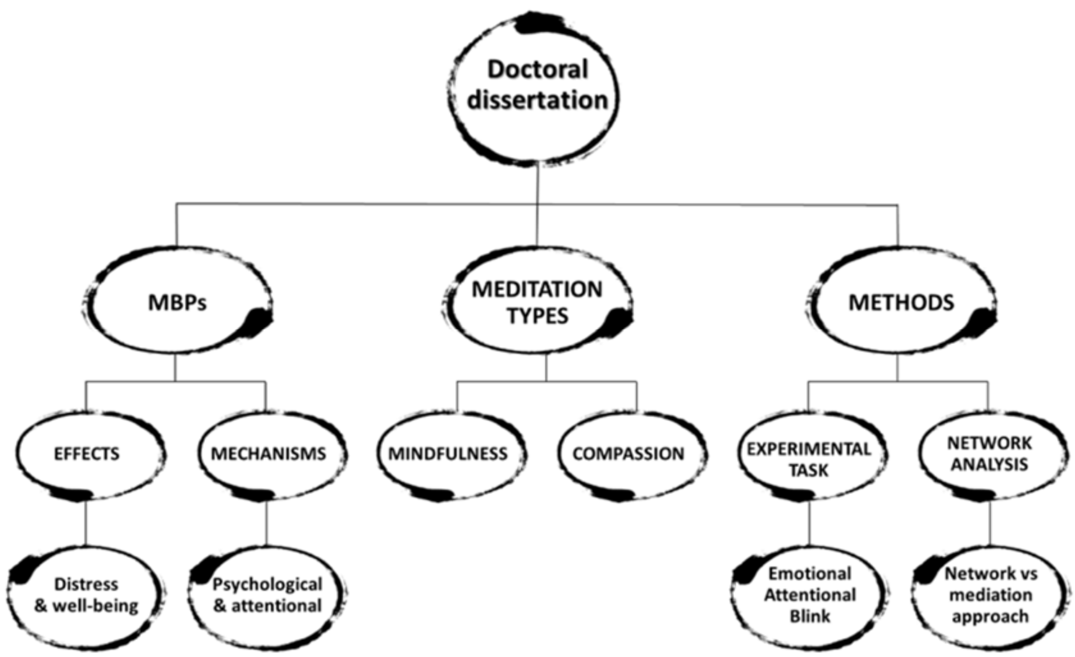
Even doing a one-minute practice like this shows that our mind is – for most of the time – wandering. For instance, during this one-minute exercise you might have thought about what your weekend will look like, or how long it will take to read this doctoral dissertation. You may have even questioned the appropriateness of including this minor exercise within the text of a rigorous doctoral dissertation. This training of awareness to one's present moment experience contrasts with our daily life experience, during which we often find our mind wandering, ruminating about the past or worrying about the future. A well-known experience sampling study found that people's mind wanders about 47% of the time – more importantly, as the mind wanders, one tends to be less happy than when one focuses on what is happening in the present moment (Killingsworth & Gilbert, 2010). Mind wandering can feel so aversive, that a majority of participants in another study preferred to receive mild electric shocks than to sit alone with their own thoughts (Wilson et al., 2014).

In light of these facts, it is not surprising that social and scientific interest in the effects of meditation has increased exponentially over the past three decades. Indeed, academia has launched an articulated effort to explore systematic methods to train our wandering minds. Before the 21st century, there were only 39 scientific publications focused on mindfulness practices; however, since 2000 almost 700 peer-reviewed scientific articles on mindfulness have been published in high impact journals (Bernstein et al., 2019; Kabat-Zinn, 2019). Likewise, the emerging social interest in meditation is reflected in the almost 30,000 articles and books published each year in the popular press and mass media related to mindfulness and meditation practices (Van Dam et al., 2018). Further, meditation practice has entered into every sector of society: health care (Greeson & Chin, 2019), education (Weare, 2019), corporations (Rupprecht et al., 2019), and even government and policy making (Bristow, 2019).

As it would expect in the early stages of a developing science, the rapid growth of meditation studies in a relatively short period of time should be interpreted with caution at the light of some methodological limitations and challenges (Davidson & Kaszniak, 2015; Rosenkranz et al., 2019; Van Dam et al., 2018). We should resist the urge to join the so-called 'mindfulness hype' and make overly enthusiastic and simplistic claims about the benefits of meditation practices (Van Dam et al., 2018). This is because the rapid dissemination of meditation's benefits has, at times, preceded sound evidence (Michalak & Heidenreich, 2018). Solid empirical evidence should be the main driving force of dissemination of meditation into contemporary mainstream settings; this idea is the leitmotiv of this doctoral dissertation and where our efforts are headed.

The main goal of the present doctoral dissertation was to examine the effects and mechanisms of change of two standardized meditation programs in secular contexts: the Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 2013) and the Compassion Cultivation Training (CCT; Goldin & Jazaieri, 2017). In order to accomplish this objective, we designed a research project combining different assessment methods (i.e., self-reports, experimental tasks and neurophysiological measures), as well as different assessment moments (i.e., pre-intervention, inter-session assessment, post-intervention, and a 3-year follow-up). The studies included in this dissertation represent only a small fraction of all the results derived from the entire project. We intend to publish the rest of our data in the coming years. Figure 1 shows a schematic representation of the structure of the dissertation.

Figure 1. Schematic representation of dissertation flow. MBPs = Meditation Based Programs.



We conducted four studies, each of which accounts for specific objectives:

First, we aimed to examine whether meditation practice modulates the attentional processing of emotional information. Theoretical and empirical models of meditation emphasize the central role of attentional control as the entry door for the rest of the mechanisms (Malinowski, 2013; Tang et al., 2015). At the same time, it has been hypothesized that the benefits of meditation on psychological distress and well-being could be partially mediated by changes in cognitive and attentional biases (Davis & Thompson, 2015; Ford & Shook, 2019; Garland et al., 2015a; Kiken & Shook, 2012; Vago & Nakamura, 2011). Thus, the study of attentional biases towards emotional stimuli is postulated as a key mechanism for understanding the effects of meditation practice. In the first study of the current dissertation (Chapter 7) we developed a novel variation of the Attentional Blink paradigm using negative, positive and neutral faces. This experimental paradigm was developed to be very sensitive to changes in the availability and use of attentional resources. The goal was to examine whether the practice of mindfulness and compassion meditation could modify the distribution of attentional resources towards emotional information.

Second, despite the wide range of research on meditation benefits to date, few studies have attempted to empirically examine the action mechanisms by which meditation produces its effects (Van Dam et al., 2018). Thus, we still do not know exactly *how* and *why* meditation works. In addition, the scope of scientific research has been focused almost exclusively on mindfulness meditation, whereas other forms of meditation have not received the scientific attention they deserve (Dahl & Davidson, 2019). In recognition of this, the second study of the current dissertation (Chapter 8) aimed to examine the relative effectiveness and mediators of change in mindfulness and compassion standardized programs. In this study, we tested (1) whether and how mindfulness and compassion meditation programs enhance mindfulness, compassion, and well-being, while reducing psychological distress (i.e., stress, anxiety and depression) and psychopathology outcomes (i.e., rumination and thought suppression); and (2) whether changes in mindfulness and compassion associated with each program, either individually (i.e., simple mediations) or simultaneously (i.e., multiple mediations), mediate changes in psychological distress and well-being.

Third, we employed alternative analytic strategies to explore changes in mechanisms associated with meditation. Despite general consensus on the need to expand research on underlying mechanisms of change in psychological interventions, researchers have questioned whether using standard statistical approaches to analyze such mechanisms is adequate (Hofmann et al., 2020). On the one hand, mediation analysis (used in the second study of this dissertation – Chapter 8) has been the dominant approach to analyze mechanisms of change in psychological interventions for decades (Hayes, 2009). The traditional mediation approach assumes that intervention changes are linear, unidirectional and contain only few variables. However, changes promoted by psychological interventions usually involved a complex matrix of bidirectional relationships between multiple variables that may change in dynamic ways in response to the intervention. As an alternative to traditional approaches, the relationship between the outcomes and mechanisms of change can best be studied using a network approach. In the last decade, network analysis has been used as an innovative framework to understand psychopathology (Borsboom & Cramer, 2013; McNally, 2016). In network analysis, the focus is transferred from the changes in individual variables to the relations between them, which may powerfully reveal structural psychological changes after a psychological intervention. Therefore, the third and fourth studies of the current dissertation employed a network analytic approach to explore the effects of mindfulness (Chapter 9) and compassion (Chapter 10) programs in terms of changes in the structure of relationships between psychological outcomes and mechanisms.

Table 1. Summary of the studies, Chapters and objectives of the current doctoral dissertation.

Main goal: To examine the effects and mechanisms of change of two Standardized Meditation Programs (MBPs) in a secular context: the Mindfulness-Based Stress Reduction (MBSR) and the Compassion Cultivation Training (CCT) programs.

Chapter	Objective
THEORETICAL BACKGROUND	
Chapter 1: Meditation-Based Programs	Review of the theoretical background regarding the standardized format and efficacy of MBPs.
Chapter 2: Meditation action mechanisms	Review of the main theoretical and empirical models of the mechanisms of change (psychological and cognitive) underlying meditation benefits. Specifically, we review the role of attention in meditation and the processing of emotional information.
Chapter 3: Meditation types	Review of some of the main taxonomies of meditation types, focusing on differences between compassion meditation and mindfulness practices.
Chapter 4: Attentional Blink	Description of the Attentional Blink (AB) paradigm, the effects of meditation in temporal attention and the use of emotional stimuli in the AB task.
Chapter 5: Network Analysis	Review of the network approach to psychology and psychopathology, as well as the potential use to analyze the effects and mechanism of psychological interventions.
CURRENT STUDY AND PUBLICATIONS	
Chapter 6: General methodology of the project	Description of the methodology and procedure of the general project covering the following studies.
Chapter 7: Attentional processing of emotional information in meditation	Study 1 examines whether the practice of mindfulness and compassion meditation could modify the distribution of attentional resources towards emotional information.
Chapter 8: Psychological effects and mechanisms of change in meditation	Study 2 examines the relative effectiveness and mediators of change in mindfulness and compassion standardized programs.
Chapter 9 and 10: Mindfulness and compassion programs from a network perspective	Study 3 and 4 explore the effects of mindfulness and compassion programs, respectively, by using network analysis.

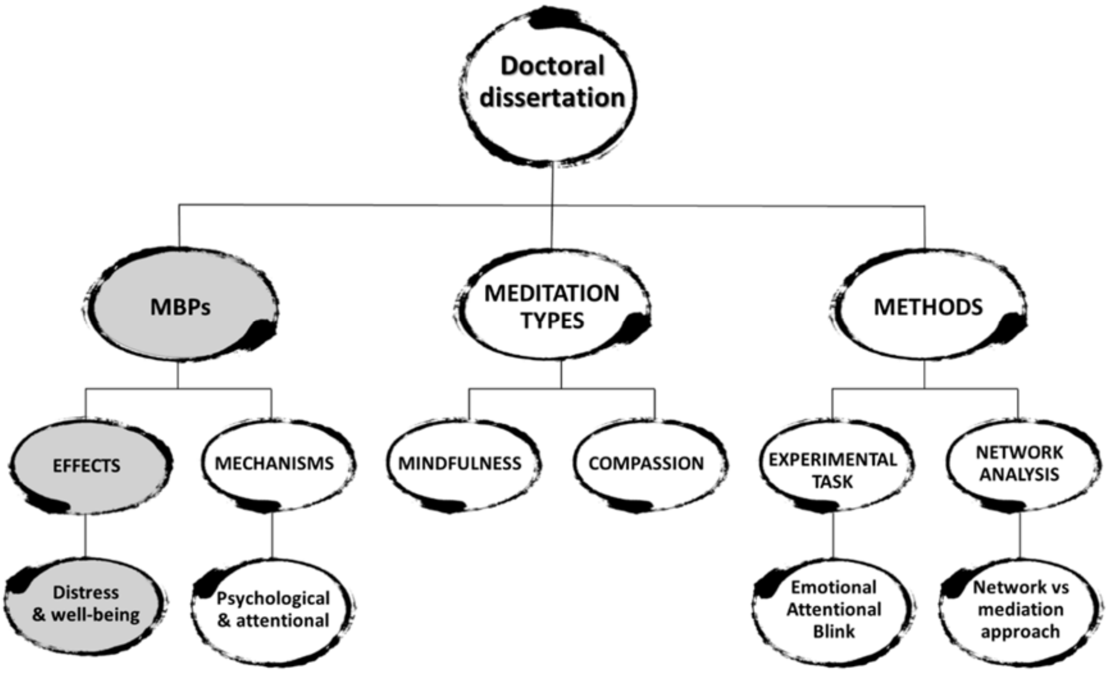
DISCUSSION AND CONCLUSIONS	
Chapter 11: General discussion	Summarizes major findings of the present dissertation and discusses them with regard to the current available evidence in the field.
Chapter 12: Clinical implications	Review of the clinical implications and the applicability of the dissertation results.
Chapter 13: Which are the next steps? Limitations and future studies	Discussion of general study limitations, future research to overcome these limitations, as well as the next steps of our programmatic research project.
Chapter 14: Conclusions	Conclusions and final thoughts regarding the research presented in the dissertation.

THEORETICAL

BACKGROUND

CHAPTER 1

MEDITATION-BASED PROGRAMS



1.1. WHY MEDITATION-BASED PROGRAMS?

Why have meditation practices attracted such strong interest in clinical psychology? A complex mixture of social, psychological and historical factors has probably influenced the rapid dissemination and acceptance of meditation practices in social and scientific fields (Bernstein et al., 2019; Kabat-Zinn, 2019; Michalak & Heidenreich, 2018; Wielgosz et al., 2019). Perhaps one of the major reasons to explain the rising popularity of meditation practices is the apparent simplicity and high feasibility of Meditation-Based Programs (MBPs), as well as the existence of well-validated standardized formats (Creswell, 2017).

At this point, let's take a step back to better understand meditation’s historical background. Some of the key pieces that promoted the emergence and growth of meditation practices in the West were the contributions by Jon Kabat-Zinn and his colleagues at the University of Massachusetts. Kabat-Zinn’s team created the first mainstream secularized meditation program, the well-known Mindfulness Based Stress Reduction (MBSR). The MBSR, explicitly designed to make meditation suitable to Western modern mind, was used to manage stress caused by chronic pain (Kabat-Zinn et al., 1985). The MBSR has become the most widely implemented meditation intervention in healthcare settings in many countries around the world. At the same time, different monastics and spiritual masters, such as Thich Nhat Hanh, Krishnamurti, Ramana Maharshi, Maharishi Mahesh Yogi, Goenka, Sai Baba, Yogananda, Osho, and Joan Halifax, just to name a few, helped to disseminate meditation principles and practices across the West. In addition, Tenzin Gyatso, the Tibetan Buddhist 14th Dalai Lama, supported a series of inter-cultural dialogues between leading scientists, monastics and practitioners hosted by the Mind and Life Institute (Hasenkamp, 2019). These events and figures have each played key roles in promoting the catalysis of contemplative practices in the West.

The meditation practices and exercises in the MBPs were mainly adapted from Buddhist tradition. During the XXI century, globalization and knowledge-sharing have facilitated the migration of the contemplative mind training coming from Eastern to Western psychology (McMahan, 2008; Wallace, 2006). However, MBPs in contemporary mainstream settings differ from those in traditional settings in two important ways: it is secular in nature and is clinically orientated.

First, while rooted in Buddhist traditions, MBPs are a new secularized formulation of meditation practices, re-contextualizing meditation within the framework of modern science and healthcare (Jinpa, 2019; Kabat-Zinn, 2019). In order to prevent cultural appropriation, it is very important to specify the contexts in which meditation will be applied, by defining the boundaries of secular and religious contexts. For instance, one would expect differences between the effects of meditation when used in a therapeutic setting as part of treatment for depression or anxiety vs. when used in a retreat context. In contrast with 'first generation' MBPs (e.g. MBSR and MBCT), the 'second generation' of MBPs seeks to recover the Buddhist roots and teaching, with an openly spiritual nature (Van Gordon et al., 2015). However, these second generation MBPs are at an earlier stage of development and research is still scarce. Hence, this dissertation is focused on first-generation MBPs.

Second, although meditation and contemplative practices were not originally developed to treat mental disorders (Davidson & Dahl, 2018), their application in clinical context resulted from interdisciplinary dialogue between the Buddhist tradition and psychological science (Anālayo, 2019). Although psychological science and Buddhism are different epistemological systems, both converge on the common goal of alleviate unnecessary suffering and promoting human flourishing through better understanding the human mind. In fact, the assumption that the mind can be trained through contemplative practices as a way to promote well-being – which is observed in contemporary and secular meditation practices –remains intact from Buddhism.

Another important reason to explain the rising popularity of meditation practices in clinical psychology and health-related contexts is the transdiagnostic approach of the MBPs to reduce psychological distress while improving well-being (Greeson et al., 2014). The transdiagnostic perspective targets a set of psychopathological processes underlying different clinical disorders (Barlow et al., 2011). Meditation promotes some common adaptive changes that may be applicable to a broad range of therapeutic targets and contexts, such as improvements in attentional control, emotional regulation, rumination, sleep difficulties, adaptative self-awareness, decentering, acceptance attitude, or the mindful exposure to distressing situations without reacting to them, among others (Greeson et al., 2014; Wielgosz et al., 2019).

Based on this modular perspective of psychopathology, several interventions have emerged combining elements from Cognitive Behavioral Therapy (CBT) with meditation practices, which helps solve some limitations in clinical psychology (Fresco & Mennin, 2019). This synergic combination has shown very promising preliminary results, as is the case of Dialectical Behavior Therapy (DBT; Linehan et al., 1999), Acceptance and Commitment Therapy (ACT; Hayes et al., 2006), the Unified Protocol (UP; Barlow et al., 2017), Emotion Regulation Therapy (ERT; Mennin & Fresco, 2014), Compassion Focused-Therapy (Gilbert, 2010), and developments in the field of Positive Psychology (Cebolla et al., 2017; Seligman & Csikszentmihalyi, 2014). Most of these therapies are included in the so-called Third-Wave Therapies (Öst, 2008), characterized by a smaller emphasis on controlling internal experience and a greater emphasis on concepts such as acceptance, meta-cognition and emotional regulation processes. However, there are some crucial differences between MBPs, CBTs and Third-Wave Therapies. One of the main differences between CBTs and MBPs is that the focus in mindfulness is *not* to change the content of one's thoughts, but rather, to change one's relationship with his/her thoughts; this involves becoming more aware of the thoughts without being attached to them (i.e., decentering), and noticing how one's thoughts affect the body and produce emotions and behaviors that were not part of the original situation. The main difference between MBPs and Third-Wave Therapies is that meditation formal practices are subsidiary components of these therapies rather than their core ingredients.

1.2. STANDARDIZED MBPS

Although each of the MBPs has idiosyncratic procedural and pedagogical differences, the gold-standard model of MBPs includes the following structural characteristics (Crane et al., 2017; Santorelli et al., 2017; Wielgosz et al., 2019):

1. Around 20-25 hours of face-to-face session through a limited program, usually 8 weeks in length.
2. A group format (10-20 participants).
3. Between 30-45 minutes of daily formal practice at home.

4. Combining formal meditation practice (e.g., with the support of recorded guidance) with informal practices (i.e., to carry out everyday activities with awareness).
5. Group dynamics and reflections about the typical experiences and difficulties encountered in the practice.
6. Focused attention as the foundation practice on which to build more complex skills.
7. The program adherence and integrity are assured by the use of standardized and empirically validated protocols (i.e., manualized intervention). Interventions are typically delivered by instructors/therapists who are officially certified by institutions of reference.

Other important features of the MBPs are:

1. The core ingredient of all the MBPs is the idea that the human mind can be systematically trained through contemplative practice as a way to reduce unnecessary psychological distress while enhancing well-being.
2. Theories and practice of MBPs are derived from the confluence of contemplative traditions, medicine, psychology and education.
3. MBPs aim to enhance attentional, emotional and behavioral self-regulation, as well as positive qualities such as (self) compassion, equanimity, kindness, curiosity, and wisdom.
4. The relevance of the didactical and psychoeducational processes, such as the physiology of stress, thought and emotion regulation, somatizations, etc.
5. Most practices are conducted sitting down, although some instruct individuals to lie on the back or engage in continuous movement (i.e., walking meditation).

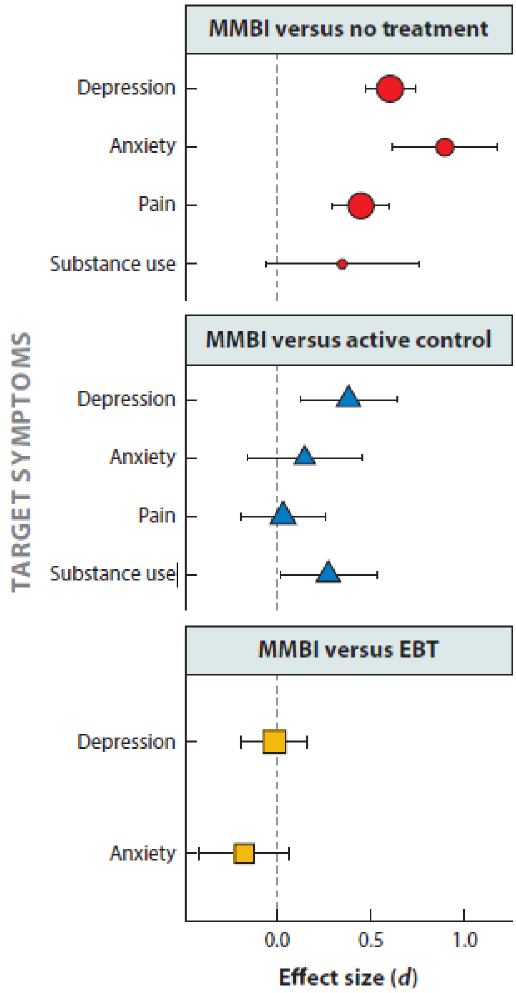
Therefore, this doctoral dissertation examines two standardized 8-week MBPs, in order to compare the effects of mindfulness and compassion practices in highly controlled environments (Davidson & Kaszniak, 2015; Van Dam et al., 2018).

1.3. EFFICACY OF MBPS

Meta-analytic evidence suggests that MBPs are a promising approach for a wide variety of mental health problems and psychopathologies (Enkema et al., 2020). Recent meta-analyses have reported that MBPs outperform no treatment, treatment as usual and active control conditions (i.e., bona fide treatments; Wampold et al., 1997), showing similar results as evidence-based treatment across various psychological disorders (Goldberg et al., 2018; Hedman-Lagerlöf et al., 2018; Wielgosz et al., 2019). For instance, across 142 non-overlapping samples (n = 12,005), Goldberg et al. (2018) found that MBPs outperformed no treatment (d = 0.55), minimal treatment (d = 0.37), non-specific active controls (d = 0.35), and specific active controls - bona fide treatments (d = 0.23), and performed on par with evidence-based treatments by APA's Division 12 (d = −0.004) (see Figure 2). Accordingly, Hedman-Lagerlöf et al.'s (2018) meta-analysis of 19 Randomized Control Trials (RCTs) has shown that MBPs were more effective than no treatment (g = 1.07) and treatment as usual (g= 0.40), but no differences were found in comparison to placebo (g = 0.17) or other active treatments (g = -0.01). MBPs also appear to benefit healthy individuals with no apparent psychopathology: Sedlmeier et al.'s (2018) meta-analysis showed a medium effect size for studies with positive control groups (r = .27), and a small but stable effect size when comparing to active control conditions (r = .17) along several psychological variables.

As shown in Figure 2 (Goldberg et al., 2018), MBPs are a particularly promising approach for reducing depression symptoms (Thimm & Johnsen, 2020), depression relapses (Kuyken et al., 2016), anxiety and stress symptoms (de Abreu Costa et al., 2019; Fumero et al., 2020), posttraumatic stress and trauma related symptoms (Hopwood & Schutte, 2017), substance use (Li et al., 2017), and eating disorders (Turgon et al., 2019), among other conditions. Despite the potential contraindications to participate in an MBP having serious mental disorders (Santorelli, 2014), in the last years MBPs have been postulated as an effective and safe intervention for psychotic symptoms (Louise et al., 2018).

Figure 2. Efficacy of MBPs for different mental health symptoms (as shown in Wielgosz et al., 2019, adapted from Goldberg et al., 2018). MMBI = Mindfulness Meditation–Based Intervention; EBT = Evidence-Based Treatment.



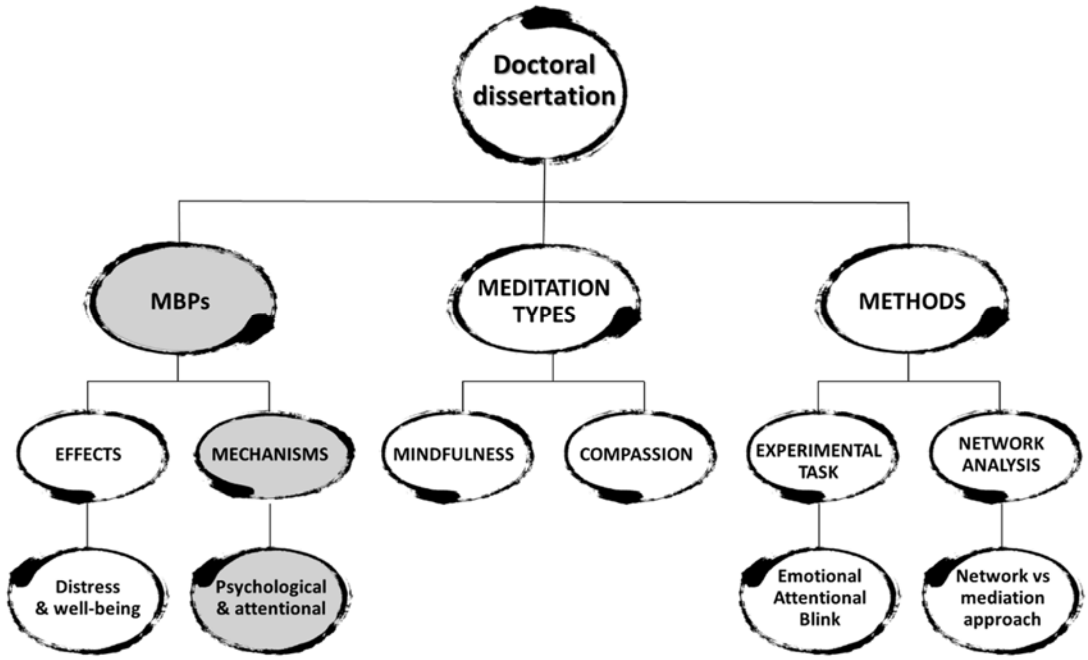
In addition to reducing symptoms of psychopathology, MBPs may also increase our psychological well-being (Brown & Ryan, 2003; Carmody & Baer, 2008), quality of life (Khoury et al., 2015), empathy, compassion and prosocial behaviors (Luberto et al., 2018). Moreover, MBPs may be a suitable 'adjunct treatment' to medical treatments. MBPs decrease psychological distress while improving quality of life and well-being in people suffering a variety of physical health problems, including cancer, cardiovascular disease, diabetes, chronic pain, neurodegenerative diseases, and HIV/AIDS (Greeson & Chin, 2019). Evidence suggests that meditation practice impacts brain structure and function, as well as epigenetic and telomere regulation (Conklin et al., 2019; Fox & Cahn, 2018; Shen et al., 2020), which may ultimately contribute to healthy aging as well as help ameliorate the neural substrates associated with psychiatric diseases.

1.4. CONCLUSIONS OF THE EFFECTS OF MBPS

Dimidjian & Segal (2015) analyzed the empirical evidence status of MBPs using the NIH Stage Model for clinical science (Onken et al., 2014). They noticed that most of the empirical evidence was saturated in Stage I (i.e., intervention generation and refinement). In addition, some basic-science studies (Stage 0) and studies testing the MBPs efficacy in clinical research (Stage II) have been conducted. In contrast, few studies have examined the efficacy of MBPs in real-world settings (Stage III). In that sense, this doctoral dissertation provides new Stage III evidence by comparing two different MBPs in naturalistic settings that employ community samples.

CHAPTER 2

MEDITATION ACTION MECHANISMS



When we hear the word 'meditation', the image of someone sitting in silence in a lotus position, with closed eyes and a fragrant incense stick burning, may come to mind. But, what is really behind these meditation stereotypes? After an initial phase of researching the benefits of meditation on physical and mental health, research must now direct its efforts to study the underlying mechanisms mediating these benefits (Malinowski, 2013; Van Dam et al., 2018) as we still do not know exactly *how* and *why* meditation works. Clarifying which mechanisms are at play would improve the efficacy of MBPs in different populations and promote the inclusion of meditation practice in psychological treatment protocols and in healthcare systems (Brown et al., 2007; Craig et al., 2008).

2.1 THE STUDY OF MECHANISMS OF CHANGE IN CLINICAL PSYCHOLOGY

There is a long tradition in clinical science of studying the processes and mechanisms of change underlying psychological interventions (Kazdin, 2007). This tradition is perfectly reflected in the classical Gordon Paul's question: "*What treatment, by whom, is most effective for this individual with that specific problem, under which set of circumstances, and how does it come about?*" (Paul, 1969, p. 44). Furthermore, the goal of investigating the mechanisms of change is aligned with modern clinical science recommendations (Hofmann & Hayes, 2019). The APA Presidential Task Force on Evidence-Based Practice (2006) was created with two main objectives: First, the study of the evidence-based treatments, and second, the study of the therapeutic mechanisms and processes of change. Despite this, researchers have paid considerably more attention to the outcomes of interventions, and less attention to the mechanisms of change (Castonguay et al., 2006). Moreover, various health and funding organizations have called for projects focused on identifying underlying components and mechanisms of change, as is the case of the National Institute of Health (NIH) priorities with the Research Domain Criteria initiative (RDoC; Insel et al., 2010).

The NIH defines 'mechanisms of change' as any psychological, social, cultural or structural variable that plays a role in initiating and/or maintaining a behavioral change (Nielsen et al., 2018). However, the term 'mechanism' could be easily confused with the notion of 'mediator'. According to Kazdin (2007), a '*mechanism'* is defined as the process responsible for the change (i.e., the reason why/how change came about), whereas a '*mediator'* would be an intervening variable that statistically accounts for the relationship between independent and dependent variable. Something that mediates the change may not necessarily be the processes through which this change happens. The term 'mechanism' reflects the processes through which an intervention (i.e., independent variable) produces outcomes (i.e., dependent variables), and thus refers to a greater level of specificity than 'mediator'. For this reason, Kazdin (2007, 2009) suggested seven requirements for establishing a mechanism of change in psychological interventions: strong association, specificity, consistency, experimental manipulation, temporal precedence, gradient, and plausibility.

2.2 MBPs Mechanisms of Change

Several models have explored the potential mechanisms of change underlying MBPs from multiple disciplines, including cognitive science, affective neuroscience, clinical psychology and Buddhist psychology. Together, these models highlight a large number of mechanisms underlying the effects of meditation, which makes it difficult to fully categorize all of them. This complexity may help explain the lack of consensus on the mechanisms underlying the effects of meditation. Most of these models propose interactions between psychological and biological factors involved in meditation practice, although more empirical studies are needed. The present doctoral dissertation seeks to contribute to the literature in this regard.

2.2.1 Psychological Mechanisms of MBPs

Various systematic reviews and meta-analyses have explored the psychological mechanisms of change in MBPs. Yet, there is no consensus about the processes mediating the effects of meditation. Furthermore, it is unclear whether these psychological mechanisms are shared across physical and psychological health conditions, or are specific to particular conditions (Alsubaie et al., 2017).

Theoretical and empirical models demonstrate that MBPs induce changes in many different variables. The reviews by Hölzel et al. (2011) and Tang et al. (2015) reveal three main psychological mechanisms: attention regulation, emotion regulation, and self-awareness (including body awareness and self-referential processes). Most theoretical models suggest that meditation enhances different cognitive and emotional processes

(Malinowski, 2013; Shapiro et al., 2006), improving psychological flexibility while reducing reactivity. At a cognitive level, meditation practice may reduce rumination and worries by enhancing cognitive reappraisal processes, including decentering and non-attachment improvements (Brown et al., 2007; Chiesa et al., 2014; Coffey et al., 2010; Garland et al., 2015b; Grabovac et al., 2011; Vago & Silbersweig, 2012). At emotional and motivational levels, meditation may reduce emotional suppression and avoidance by enhancing adaptative emotional and attitudinal processes, including acceptance and (self) compassion (Baer, 2003; Chiesa et al., 2014; Grabovac et al., 2011; Lindsay & Creswell, 2017). At a behavioral level, such cognitive and emotional improvements would reduce experiential avoidance by enhancing exposure to present moment experiences and acting with awareness (Baer, 2003; Brown et al., 2007; Malinowski, 2013; Shapiro et al., 2006). Several models also emphasize the importance of prosocial and ethical components of the practice (Grabovac et al., 2011; Vago & Silbersweig, 2012).

Further, some preliminary systematic reviews and meta-analyses have examined the psychological mechanisms underlying the effects of MBPs. The systematic review and meta-analysis by Gu et al. (2015) identified the following mechanisms underlying the benefits of MBPs: 1) Strong and consistent evidence for cognitive and emotional reactivity; 2) moderate evidence for increased mindfulness and decreased rumination and worry; and 3) preliminary but insufficient evidence for self-compassion and psychological flexibility. In the specific case of the Mindfulness-Based Cognitive Therapy (MBCT) for the treatment of depression, van der Velden et al.'s (2015) systematic review found strong evidence for mindfulness, rumination, worry, compassion, meta-awareness, and preliminary evidence for attention, memory specificity, self-discrepancy, emotional reactivity and affect (both negative and positive). Finally, the systematic review by Alsubaie et al. (2017) on the effect of MBPs on people with physical and psychological conditions revealed global changes in mindfulness levels as the most consistent mechanism of change.

A summary of the main psychological mechanisms and their definition is presented in Table 2.

Table 2. Psychological mechanisms involved in meditation.

Mechanism	Description
Mindfulness (present moment awareness or attentional control)	The ability to pay attention to the present moment, both internally (i.e., emotions, thoughts and bodily sensations) and externally (i.e., environmental stimuli), as non-reactively, non-judgmentally, and openheartedly as possible (Kabat-Zinn, 1990; Kabat-Zinn & Hanh, 2009). In the MBPs, present-moment awareness is cultivated through the focus on the meditation object (i.e., anchor), usually a sensation in the body such as the breath or the weight, returning the attention to the present moment whenever the person is distracted.
Decentering (dereification or cognitive defusion)	The meta-cognitive ability to observe the objects that arise in the mind (i.e., perceptions, thoughts, feelings, or memories) with a healthy psychological distance, self-awareness and perspective-taking (Fresco et al., 2007). In the MBPs, decentering is cultivated through recognizing that one's thoughts and feelings are no longer experienced as 'real objects' in the world, but rather as 'mental objects'. In turn, decentering could be decomposed into three interrelated components (Bernstein et al., 2015): meta-awareness, disidentification from internal experiences, and reduced reactivity to thought content.
Non-attachment	The absence of fixation on experiences, as well as an absence of internal pressure to get, hold, avoid, or change these experiences (Sahdra et al., 2016; Sahdra et al., 2010). Non-attachment also refers to being in touch with present-moment experiences with the firm belief that one's happiness is determined by the self and is independent of any external influence (Khong, 2009). The concept of non-attachment seems to significantly overlap with decentering and equanimity, however, there are slight differences between them (Bhambhani & Cabral, 2016).
Body awareness (interoceptive awareness or somatic awareness)	The ability to notice subtle bodily sensations (Mehling et al., 2009, 2012). A common foundation of mindfulness practice involves developing a greater awareness of diverse body sensations. In mindfulness, the attentional focus is usually directed to an object of internal experience, such as breathing or other bodily sensations.

Emotion regulation	The modification of ongoing emotional responses through the action of regulatory processes (Ochsner & Gross, 2005). Emotion regulation is an umbrella term for a wide range of strategies altering the emotional response. Although meditation practice has shown to improve different emotion regulation strategies, its strongest and most adaptive effects have been observed in cognitive reappraisal and acceptance.
Cognitive reappraisal	The ability to reinterpret the meaning of a stimulus in order to change one's emotional response to that stimulus (Buhle et al., 2014; Ochsner & Gross, 2005). Mindful emotion regulation leads to increases in positive reappraisal (Garland et al., 2015b), the adaptive process through which stressful events are reconstructed as meaningful or even beneficial.
Acceptance	An orientation of receptivity and non-interference with present-moment experiences (Lindsay & Creswell, 2019), attained by promoting an attitude of nonjudgment, openness and receptivity toward internal and external experiences (Baer et al., 2004; Brown & Ryan, 2003; Desbordes et al., 2015). Thus, acceptance is opposite to experiential avoidance of negative experiences (e.g., avoidance of unwanted thoughts and feelings) or approaching or sustaining pleasant experiences.
Compassion	Compassion is a multifactorial concept that includes four components (Jinpa, 2010): 1) Cognitive factor ("awareness"): to be aware of one's and others' suffering; 2) Affective factor ("sympathetic"): to be emotionally moved by one's and others' suffering, and possess a caring and tender concern; 3) Intentional factor ("wish"): a genuine wish to relieve that suffering; and 4) Motivational factor ("responsiveness"): to actively engage in behaviors that help relieve that suffering.
Self-Compassion	According to the definition proposed by (Neff, 2003), self-compassion include three main components: 1) Self-kindness: being kind and understanding toward oneself, rather than being harshly self-critical; 2) Common humanity: perceiving one's experiences as part of the larger human experience (e.g., suffering is an unavoidable part of the human condition), rather than seeing them as separating and isolating; and 3) Mindful self-compassion: holding one's painful thoughts and feelings in balanced awareness, rather than over-identifying with them.
Empathy and prosocial behaviors	Empathy is defined as the ability to understand and feel what other person is experiencing from their frame of reference (Bellet & Maloney, 1991). Prosocial behavior is considered as a subcomponent, and potential consequence, of empathy (Batson, 2009). Research findings suggest that meditation increases both empathy (Bayot et al., 2020) and prosocial behavior (Condon, 2019).

Well-being and life satisfaction	As previously stated, one of the main goals of meditation practice is to enhance well-being and human flourishing. Psychological well-being is composed by hedonic and eudaimonic components, as well as remembered and experienced elements (Hervás & Vázquez, 2013). Life satisfaction is considered as the cognitive-evaluative part of well-being (Pavot & Diener, 1993).
Self-related processing	The ability to reduce narrative autobiographical thoughts while enhancing an awareness of the present-moment state of the self, avoiding the maladaptive perception of the self as a discrete and unchanging entity (Desbordes, 2019). In MBPs, changes in self-related processing are cultivated through decentering one's self-concept and decreasing one's narrative thinking. Importantly, although traditional Buddhist contexts explicitly target the 'self-shifts' as a primary goal of the practice, secular MBPs do not.

2.2.2 MBPs COGNITIVE MECHANISMS

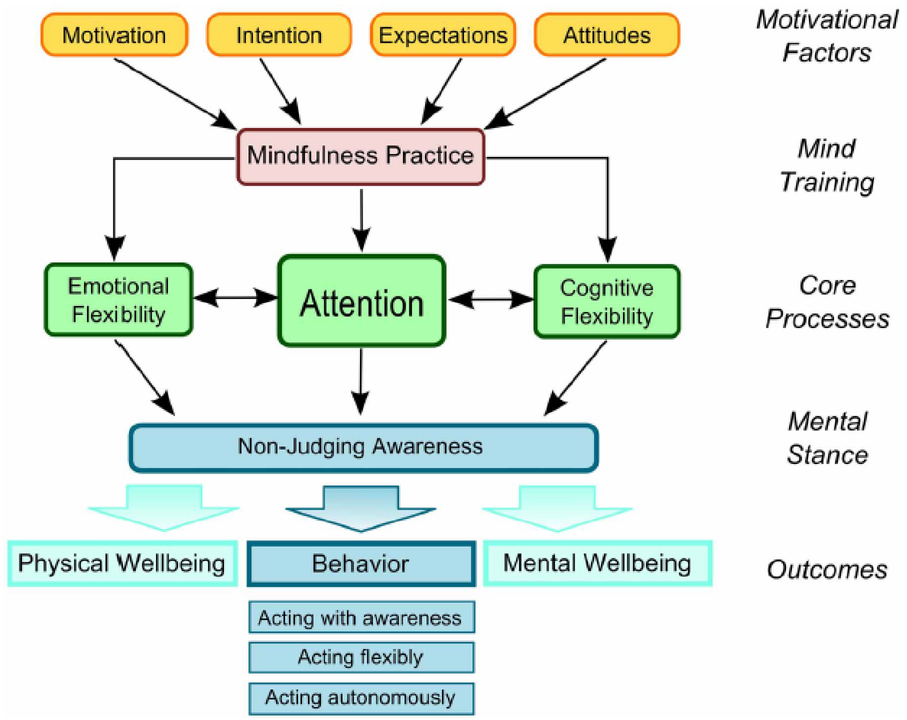
One potential pathway by which MBPs may improve mental health while promoting well-being is through changes in the cognitive system. As mentioned above, meditation is commonly defined as a systematic form of mental training (at least in part). Thus, it seems logical to think that meditation may improve some adaptive cognitive processes. Several models have been developed to describe the impact of meditation on cognitive processes.

Several pioneer cognitive models in meditation emphasized the central roles of three cognitive components (Hölzel et al., 2011; Vago & Silbersweig, 2012): 1) Attention regulation: improvements in alerting, sustaining, orienting, monitoring, as well as reductions in attentional biases; 2) Memory extinction and reconsolidation towards more adaptive trajectories; and 3) Inhibition and switching: improvements in decentering from thoughts, inhibitory control from distractions, disengagement from irrelevant targets and flexible engagement on relevant features of tasks. The systematic review carried out by Chiesa et al. (2011) found that early phases of mindfulness training (characterized by the development of focused attention) are associated with improvements in selective and executive attention, whereas advanced phases (characterized by an open monitoring of internal and external stimuli) are associated with improvements in unfocused sustained attention. This evidence suggests that MBPs would enhance both working memory and executive functions.

2.3 THE ROLE OF ATTENTION IN MEDITATION

As noted above, various models emphasize the central role of attentional control, viewing it as the ‘entry door’ for the rest of mechanisms (Chiesa et al., 2011; Hölzel et al., 2011; Malinowski, 2013; Tang et al., 2015). One of the theoretical models that most inspired this doctoral dissertation was the Liverpool Mindfulness Model (LMM) (Malinowski, 2013), which provides a comprehensive framework for studying the elements involved in the practice of meditation. The LMM gives the development of attentional skills a central role in the process of change: within this framework, the training of attentional skills is a catalyst for greater emotional and cognitive flexibility, greater non-judgmental awareness of one’s thoughts, feelings, and experiences, and behavioral changes that promote well-being and positive health outcomes. The LMM structures the processes involved in meditation practice into five different tiers (Figure 3): 1) Motivational factors: motivation, intention, expectations, and attitudes that determine whether and how an individual engages in meditation training; 2) Mind training: achieved through the practice of mindfulness; 3) Core processes: the regular practice of mindfulness develops and refines the attentional functions that facilitate emotional and cognitive regulatory processes; 4) Mental stance (i.e., attitude): improvements in non-judgmental awareness, resulting in a more balanced mental stance; and 5) Positive outcomes: this balanced mental stance results in different positive outcomes (e.g., physical and mental well-being).

Figure 3. Liverpool Mindfulness Model (Malinowski, 2013).



Beyond nominalist debates, when mindfulness definitions are analyzed together, one may notice that the word 'attention' is the core component linking inexorably all the definitions (Grossman et al., 2004; Jha et al., 2007; Kabat-Zinn, 1994; Walsh & Shapiro, 2006). Moreover, various meditative traditions highlight the importance of regulating our attention in the early stages of the practice (Dahl & Davidson, 2019; Tang & Posner, 2009). Meditative traditions have given this process different and unique names: *samadhi* in Theravada Buddhism (Hart, 1987), *samatha* in Tibetan Buddhism (Lutz et al., 2007), or *dharana* in the practice of Yoga in India (Devananda, 1999), among others. In the Buddhist tradition, the *Satipatthana Sutta* describes the four foundations of attention

(2008): 1) Mindfulness of the body (*kaya*); 2) Mindfulness of feelings or sensations (*vedana*); 3) Mindfulness of mind or consciousness (*citta*); and 4) Mindfulness of mental objects or categories (*dhammas*).

Attention regulation is one of the mechanisms of change in meditation that has received more empirical support in the last years (Chiesa et al., 2011; Hölzel et al., 2011; Malinowski, 2013; Tang et al., 2015). It is also a key component of mindful emotion regulation processes (Guendelman et al., 2017). Overall, research to date seems to suggest that meditation practice would increase the efficiency of attentional functions, thereby improving attentional control processes (Malinowski, 2013; Moore et al., 2012). Specifically, meditation practice seems to improve earlier stages of stimulus processing in terms of enhanced consistent, dynamic and flexible attentional functions, which improves resource allocation during early stages of the processing and, in turn, enhances subsequent processing (Malinowski, 2013).

One of the first attempts to systematize the role of attention in mindfulness practice was the model proposed by Bishop et al. (2004), which included two different cognitive processes: 1) the self-regulation of attention, characterized by full attention of internal and external experiences; and 2) the attitude of acceptance, openness and non-judgment (see also Brown & Ryan, 2003; Lindsay & Creswell, 2017). This model also suggests that mindfulness practice would train four attentional components: 1) sustained attention: the ability to maintain a state of vigilance/awareness in present-moment experiences for long periods of time; 2) attention switching: the ability to flexibly shift attention from one object to another, redirecting attention to the present moment when it wanders; 3) inhibition of elaborative processing: the ability to avoid ruminating thoughts, feelings or sensations that are outside of the present moment; and 4) non-directed attention: the ability to attend to present moment experiences in an impartial way, free of bias from assumptions or expectations.

On a phenomenological level, the meditator would advance through the following phases along the practice (see Figure 4; Malinowski, 2013):

1. *Focus on object (sustained attention phase - alerting network)*: the meditator begins by focusing on the meditation object (e.g. somatosensory sensation of breathing).

2. *Mind wandering (distraction phase - default mode)*: during the attention focusing phase, sometimes the mind wanders and the meditator loses the focus on the object.

3. *Recognize wandering (monitoring phase - salience network)*: sooner or later, the meditator will recognize that his/her mind wandered.

4. *Letting go (disengagement phase - executive network)*: when mind-wandering is detected, the meditator tries to let go of distracting thoughts or experiences with an accepting and non-judgmental attitude.

5. *Return to object (shifting the attention phase – (re) orienting network)*: the meditator releases distracting thoughts and returns his/her attentional focus to the meditation object (e.g. somatosensory sensation of breathing).

Although these are described as five separate phases, the processes occur in parallel and often overlap. This complex sequence, which is repeated several times during the practice of meditation, can last either a few seconds or extend over longer periods of time. For a beginner, longer periods of mind wandering may pass without active recognition; however, with greater practice, periods of sustained focus and attentional stability may become longer (Wallace, 2006).

Figure 4. Representation of the meditation process (Malinowski, 2013). 1) The inner circle represents the phenomenological level; 2) The middle circle represents the attentional process involved; and 3) The external circle represents the brain networks involved in the processes.

Data from both behavioral tasks (e.g., the Attention Network Test or the Stroop task) and neuroimaging studies seem to indicate that the executive network is the most relevant subcomponent to explain the effects of meditation on attentional regulation processes (Jha et al., 2007; Tang et al., 2015; van den Hurk et al., 2010). Meditation practice requires continuous monitoring and redirecting of one's attentional focus, at least until a level of expertise is achieved and attentional stability can be maintained with little effort (Brefczynski-Lewis et al., 2007; Tang et al., 2012). For instance, in focused meditation, internal and external distractors are conceptualized as a conflict monitoring task; when the person becomes aware that has been distracted, the individual exercises his/her executive network in order to redirect attention to the selected target (e.g., breath) (Hölzel et al., 2011). In fact, several studies have found that meditation practice improves conflict monitoring (Chan & Woollacott, 2007; Chiesa et al., 2011; Moore & Malinowski, 2009; Slagter et al., 2007; Tang et al., 2007; Wenk-Sormaz, 2005).

Meditation has also been found to affect two other attentional networks: the alerting network and the orienting network. Long-term meditation appears to produce significant and positive changes within the alerting network (Jha et al., 2007; MacLean et al., 2010; Tang et al., 2007). For example, improvements in the alerting network have been found in expert meditators after a one-month retreat (Jha et al., 2007) and after a three-month Samatha retreat (MacLean et al., 2010). Regarding the orienting network, improvements have been found using longer training periods (MacLean et al., 2010), after 8 weeks of MBSR (Jha et al., 2007) and in expert meditators compared with novices (van den Hurk et al., 2010). Moreover, some studies have revealed the effects of meditation on other attentional functions, such as the Attentional Blink effect (Slagter et al., 2007), a measure of temporal attention reflecting the flexibility and distribution of attentional resources, and intimately linked to executive attention (for more information see Chapter 4).

Notwithstanding the research to date, there still remain ambiguities on how meditation practice changes different subcomponents of attention. In addition, the results discussed could be moderated by a variety of factors, such as the type of meditation, the intensity and quality of the practice, or the comparison control group. Thus, more research is needed to systematize the effects of meditation on attention.

2.4 MEDITATION AND ATTENTIONAL PROCESSING OF EMOTIONAL INFORMATION: WHAT DO WE KNOW SO FAR?

When you observe things through the lens of mindfulness, whether it be through formal meditation practice or in daily living, you invariably begin to appreciate things in a new way because your very perceptions change. Kabat-Zinn (1990, p. 154).

As mentioned above, a growing body of studies support the efficacy of MBPs for reducing emotional distress (Hoge et al., 2019) and promoting psychological well-being (Carmody & Baer, 2008). However, we know surprisingly little about the mechanisms through which meditation produces these positive effects. It has been hypothesized that these benefits could be partially mediated by changes in cognitive and attentional biases (Conklin et al., 2019; Davis & Thompson, 2015; Ford & Shook, 2019; Garland et al., 2015a; Kiken & Shook, 2012; Roberts-Wolfe et al., 2012; Vago & Silbersweig, 2012), which may be key mechanisms for understanding the effects of meditation practice. Because meditation promotes a non-judgmental and accepting stance toward one's experiences (i.e., engaging with negative, positive and neutral experiences equally rather than avoiding or focusing on certain experience more than others) (Bishop et al., 2004; Kabat-Zinn, 1994), meditation is thought to promote a less biased and more balanced attention to emotional information.

2.4.1 ATTENTIONAL PROCESSING OF EMOTIONAL INFORMATION AND PSYCHOPATHOLOGY

Attention is often biased toward emotionally significant stimuli. Our attentional system enhances the processing of salient stimuli by selecting them from the environment in which they are embedded (Corbetta & Shulman, 2002), eliciting the motivation to either approach or avoid these stimuli (Friedman & Förster, 2010; Lang & Bradley, 2010). However, the engagement of attentional resources by a given stimulus is not only determined by the characteristics of the stimulus itself (e.g. valence), but also by higher cognitive systems acting upon the representation of the stimulus. For instance, we tend to select and sustain our attention on mood-congruent objects more rapidly than on those who are not congruent with our emotional state (Mathews & MacLeod, 2005).

A 'bias' is defined as the tendency to process emotional stimuli differently in comparison to neutral ones. Attentional biases include three components (Cisler & Koster, 2010; Posner & Petersen, 1990): 1) An initial attentional shifting and orientation toward a certain stimulus; 2) Engagement with the stimulus; and 3) Difficulties in disengagement from the stimulus. Evolutionary theories and empirical evidence show that humans have both a negativity bias (Baumeister et al., 2001; Rozin & Royzman, 2001) and a positivity bias (Diener et al., 2014; Sharot & Garrett, 2016). The negativity bias refers to the tendency to pay greater attention to negative information, while the positivity bias refers to the tendency to pay selective attention to positive information when significant negative stimuli are not presented (which in turn would promote the positive mood offset in healthy individuals).

Cognitive theories of depression and anxiety suggest that negatively biased cognitive styles in general, and attentional biases in particular, are a key transdiagnostic factor for understanding the etiology and maintenance of different psychopathologies (Beck, 1987; Riskind, 1997), as is the case of mood disorders, addictions or pain distress (Field & Cox, 2008; Gaffiero et al., 2019; Van Bockstaele et al., 2014). These models are based on the idea that distressed individuals process emotional information differently than do healthy individuals; in other words, people in distress may exhibit greater negativity bias and lesser positivity bias. Specifically, individuals experiencing high levels of depression exhibit reduced orientation toward positive stimuli and an increased maintenance of attention on negative stimuli, while those experiencing high levels of anxiety are typically hypervigilant to, and resistant to the disengagement from, threatening stimuli (Armstrong & Olatunji, 2012). Both the presence of negative biases and/or the lack of positive biases play a key role in causing and maintaining psychological disorders (Diener et al., 2014; Mathews & MacLeod, 2005). Several interventions aimed at modifying such cognitive and attentional biases have emerged in the last years, grouped into the so-called Cognitive and Attentional Bias Modification procedures (Browning et al., 2010; Hakamata et al., 2010; Jones & Sharpe, 2017). Interestingly, preliminary evidence supports the potential use of meditation practice as a feasible alternative to modify the processing of emotional information (Beard, 2011).

2.4.2 PROCESSING OF EMOTIONAL INFORMATION IN MEDITATION: EMPIRICAL EVIDENCE

Meditation practice has shown to change our response to emotional stimuli. On one hand, some studies have found that meditators seem to favor the processing of positive information as compared to negative information (Erisman & Roemer, 2010; Pavlov, Korenyok, et al., 2015; Roberts-Wolfe et al., 2012). On the other hand, several studies have indicated that meditation may reduce interference from affective information (Ortner et al., 2007), having found no differences in the attentional processing of different emotions as a result of meditation practice (Blanco et al., 2020; Brown et al., 2013).

Trait mindfulness has shown to modulate the neural responses to emotional stimuli in early stages of emotional processing, reducing brain reactivity to emotional information (both pleasant and unpleasant) (Brown et al., 2013). Similarly, long-term meditation has shown to yield a similar cardiovascular reactivity for negative, positive and neutral stimuli, whereas no meditators have a higher cardiovascular reactivity toward negative stimuli as compared to neutral and positive ones (Pavlov, Reva, et al., 2015). Meditators seem to achieve reduced reactivity to, and interference of, emotional information through a variety of mechanisms. Taylor et al. (2011) found a deactivation of default mode network during emotional processing across all valences of stimuli in experienced meditators, and a down-regulation of the left amygdala in beginners. These results suggest that long-term meditation practice enhances emotional stability by promoting acceptance of emotional information and present-moment awareness, whereas short-term meditation practice enhances emotional stability by eliciting control over low-level affective systems. A recent systematic review of the effects of meditation practice on the neural processing of negative stimuli showed that meditation practice prompts regulatory mechanisms (i.e., greater prefrontal and insular activity) when participants face negative stimuli, even without an explicit request of using regulatory strategies (Magalhaes et al., 2018).

Some pioneer studies over the past decade have assessed cognitive and attentional biases in meditation. De Raedt et al. (2012) found that a standardized mindfulness intervention, compared to a control group, showed a reduced facilitation of attention for negative information and a reduced inhibition of attention for positive information among individuals with recurrent major depression, which would be an indicative of open attention towards all emotional information. This conclusion is supported by eye-tracking studies, where meditators have been found to spend significantly less time looking at negative faces (Blanco et al., 2020; Pavlov, Korenyok, et al., 2015), and show a greater pupillary contraction and a smaller dilation to negative stimuli than a control group (Vasquez-Rosati et al., 2017). Interestingly, these changes in attentional biases have also been found among individuals suffering different pathological conditions: meditation practice reduces attentional biases to threat and pain related stimuli in chronic pain and fibromyalgia patients (Garland & Howard, 2013; Vago & Nakamura, 2011), and reduces attentional biases to addiction-related cues in patients with alcohol dependence (Garland, 2011; Garland et al., 2012; Garland, Gaylord, et al., 2010).

Researchers investigating the effect of meditation on other cognitive biases have found similar results. For instance, Roberts-Wolfe et al. (2012) found an increase in memory bias toward positive information after a standardized meditation training; notably, this positive memory bias was related to improvements in psychological well-being and reductions in depression and anxiety. Negative interpretation bias has shown to mediate the relation between trait mindfulness and emotional distress (Ford & Shook, 2019). Furthermore, meditators exhibit a weaker negativity bias on an objective measure of attitude formation, improving the categorization of positive information (Kiken & Shook, 2011), which in turn mediated the inverse relation between trait mindfulness and emotional distress (Kiken & Shook, 2012).

Taken together, these results highlight the effects of meditation on emotional information processing, as well as the potential role of meditation for cognitive and attentional bias modification (Conklin et al., 2019; Davis & Thompson, 2015; Ford & Shook, 2019; Garland et al., 2015a; Kiken & Shook, 2012; Roberts-Wolfe et al., 2012; Vago & Nakamura, 2011). Thus, meditation practice may promote a more balanced attention to emotional information by reducing negative information bias and promoting a less biased attention of all stimuli (i.e., broad attention) – including some positive and neutral stimuli previously unattended (Davis & Thompson, 2015; Garland et al., 2015a; Kiken & Shook, 2011) – which, in turn, may alleviate psychological distress while promoting well-being (De Raedt et al., 2012; Ford & Shook, 2019; Kiken & Shook, 2012; Roberts-Wolfe et al., 2012).

Although research is scarce, other types of meditation (aside from mindfulness meditation) may produce similar changes. Preliminary results indicate that prosocial meditation (i.e., compassion and loving-kindness) also lessens cognitive and attentional biases (Desbordes et al., 2012; Feldman et al., 2010). For instance, compassion has shown to reduce implicit biases, which increases helping behaviors toward out-groups and decreases discriminatory behaviors (Kang et al., 2014; Stell & Farsides, 2016). One study also suggests that 8-week mindfulness and compassion trainings produce stable neurological changes in response to emotional stimuli (Desbordes et al., 2012): while the mindfulness group showed an overall decrease in amygdala activation when viewing images of any valence (i.e. negative, positive and neutral), the compassion group showed an increase in amygdala activation in response to negative images.

2.4.3 Phenomenology of Attentional Processing of Emotional Information in Meditation: the Role of Equanimity

Improvements in the balance of emotional information processing in meditators could also be interpreted as an indicator of equanimity (Nhat Hanh, 1999; Wallace & Shapiro, 2006). Equanimity can be defined as an even-minded mental state towards all experiences, regardless of their hedonic tone (Desbordes et al., 2015; Hadash et al., 2016). Therefore, equanimity would allow a less biased awareness and could be understood as an emotional regulation strategy, promoting a faster recovering from emotional information (Desbordes et al., 2015).

During their practice, meditators are taught to recognize when their mind wanders to distressing thoughts, emotions or sensations, and observe these experiences in a less biased manner, without judgment and with an acceptance attitude. Meditators are taught to disengage and return the attentional focus back to the meditation anchor (e.g. breath) as a way of decentering from distressing stimuli and the resulting emotional reactions (Carmody, 2009). Thus, the acceptance and non-judgment attitude would promote a less biases attention to emotional experiences (Brown et al., 2007; Shapiro et al., 2006).

2.4.4 THE "FEELING TONES": HOW THE BUDDHIST TRADITION EXPLAINS THE PROCESSING OF EMOTIONAL INFORMATION

The link between meditation practice and the processing of emotional information is embodied in the Buddhist concept of 'feeling tones' or *vedanas* (Batchelor, 2019; Grabovac et al., 2011). The feeling tones are defined as the unpleasant, pleasant, and neutral hedonic tones of our experiences that arise from the interaction between our senses and the environment. These feeling tones do not reside in the object of perception, but are instead constructed by the individual who is interacting with the environment. This means different people might experience different feeling tones when confronted with the same event or circumstance. Our habitual reaction to the feeling tones is to avoid the unpleasant and to approach the pleasant. The Buddhist terms for this approach/avoidance reactions are 'attachment' and 'aversion' (Grabovac et al., 2011). We commonly think that we approach and avoid an object itself; yet, from a Buddhist perspective, the attachment and aversion arise in reaction to the feeling tones per se, rather than to the object.

In Buddhist tradition, human suffering comes from our automatic tendency to become attached to both pleasant and unpleasant feeling tones, which influences our thoughts, emotions and behaviors (Batchelor, 2019). Due to their rapid and automatic nature (constantly arising and passing away), these feeling tones serve as powerful triggers of thoughts, emotions and behaviors that can lead to suffering. According to the Satipatthana Sutta (Thanissaro, 2008), mindfulness of feeling tones is the second foundational practice. In this view, meditators should learn to be mindful of feeling tones arising from present-moment experiences and should develop a non-attachment and acceptance attitude toward them (Batchelor, 2019). Although neutral stimuli may seem boring or uninteresting in Western societies, from a meditative perspective, neutral feeling tones are a source of restful and peaceful states, and practitioners should learn how to transcend the 'boring' to a 'quiet contentment'. Furthermore, it is also important to be aware of pleasant feeling tones to help us to re-equilibrate the effect of unpleasant feeling tones, in order to achieve a neutral baseline (Batchelor, 2019). All of these features are clearly reflected in the first study of the dissertation (see Chapter 7).

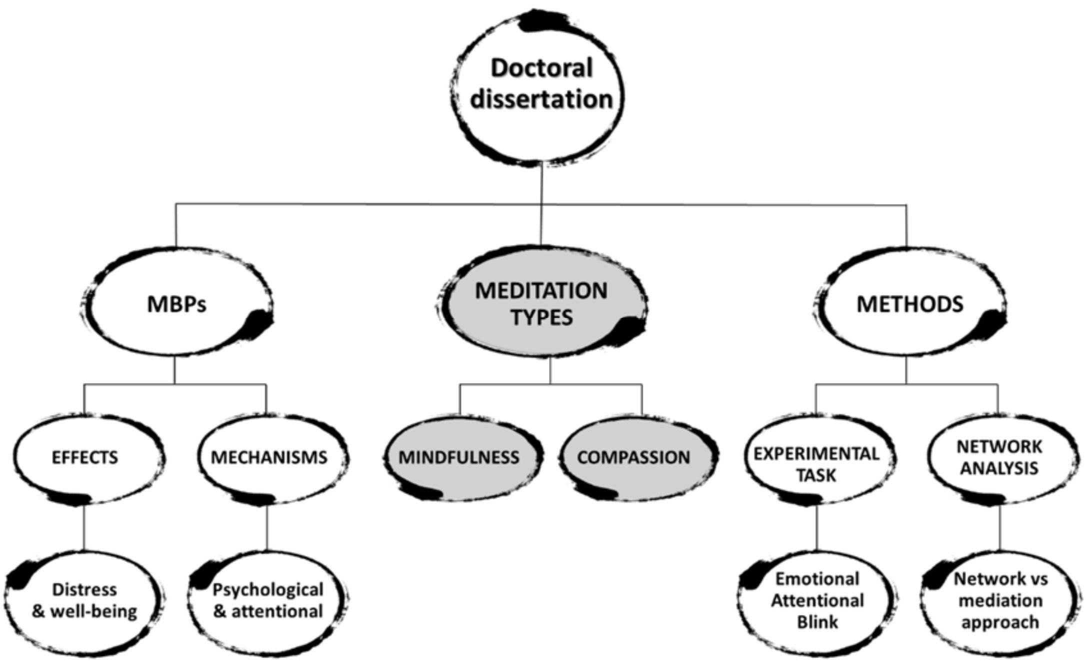
2.5 CONCLUSIONS ON THE COGNITIVE AND AFFECTIVE MECHANISMS IN MEDITATION

As previously mentioned, there is promising initial evidence on how meditation practice changes cognitive and affective processes. Nevertheless, research remains at a preliminary stage, and more research is needed (Vago et al., 2019). The effects of meditation practice on cognition and attention have been traditionally evaluated via behavioral measures (i.e., cognitive experimental tasks). However, the following methodological issues may arise when using such tasks (Vago et al., 2019; Van Dam et al., 2018): 1) Some behavioral measures have shown questionable reliability (Rodebaugh et al., 2016); 2) Clinical studies sometimes include cognitive tasks as secondary outcomes, and are thus not powered enough to detect group differences (e.g., several studies analyzing the cognitive effects of meditation have used small samples); 3) Comparing treatment conditions to active control conditions may result in ceiling effects, as control groups usually do not match the non-specific contextual factors of the MBPs, making it difficult to disaggregate these common factors from cognitive changes (e.g. participant expectations, group adherence, the role of informal practice, etc.); 4) The relationship between practice length and cognitive improvements is not always clear: some studies have reported that the magnitude of cognitive improvements are closely linked to practice length, while others have failed to find this association. Furthermore, interpreting neural changes resulting from meditation practice depends on reverse inference (i.e., from the brain activity to the behavior), which makes accurate interpretation more difficult (Vago et al., 2019).

For these reasons, future studies are needed to clarify the effects of meditation practice on cognition, attention, and the processing of emotional information. Researchers should develop novel cognitive tasks, as well as variations of existing ones, to explore the intersection between cognition and affective mechanisms, and replicate previous results in high-powered, well-controlled studies with large samples. In the present doctoral dissertation, we have tried to address some of these obstacles using a new variant of the classical Attentional Blink Task with emotional stimuli (see Chapter 7).

CHAPTER 3

MEDITATION TYPES



3.1 THE LACK OF A CLEAR DEFINITION

Meditation, as a concept, is difficult to define in a precise way. It is challenging to operationalize and measure a phenomenon that integrates practices from many different traditions. But, where do we draw the line between what can, and cannot, be labelled 'meditation'? Can lift weights or ironing one's shirt be considered a meditation practice? Meditation in general, and mindfulness meditation in particular, is an umbrella term used to characterize a state, a trait and a group of practices (Lutz et al., 2015; Vago & Silbersweig, 2012). Within this umbrella term, we give the same 'meditation' label to a brief exercise from a mobile app as we do to a month-long meditation retreat. Further, we use the same questionnaires to evaluate someone who has spent 20 years meditating and a beginner meditator after a MBSR (Van Dam et al., 2018).

In short, there is no universal definition for 'meditation'. This semantic ambiguity makes it difficult to compare results from different studies. Buddhist scholars have noted a great variety of meditation and mindfulness definitions in ancient texts (Bodhi, 2011). However, the differences between Buddhist and modern psychological definitions of meditation are inevitable and not necessarily problematic (Baer, 2019). It is likely that these differences reflect the need to operationalize a measurable definition within the contexts of contemporary psychological science and mainstream Western practices.

Beyond nominalist debates, for the purpose of this doctoral dissertation meditation is operationalized as a systematic form of mental training aimed at reducing unnecessary suffering (psychological distress) while promoting human flourishing (psychological well-being) by monitoring and regulating attention, perceptions, thoughts, emotions, and physiology. This definition, although apparently simplistic and reductionist, has been used in previous work (Fox & Cahn, 2018; Lutz, et al., 2008; Tang et al., 2015). Regarding 'mindfulness meditation', we have employed the classic definition by Kabat-Zinn (1990, 2013), which describes mindfulness as moment-to-moment awareness cultivated by paying attention to the present moment and being as non-reactive, non-judgmental, and openhearted as possible (Kabat-Zinn, 1990, 2013). This definition has two main elements: the attention itself (the 'what') and the qualities of the attention (the 'how') (Baer, 2019; Linehan, 1993).

3.2 TAXONOMY OF MEDITATION TYPES

Despite the growing interest in meditation practice, the scope of scientific research has been focused almost exclusively in mindfulness practice and other forms of meditation have not received the scientific attention they deserve (Davidson & Dahl, 2018; Van Dam et al., 2018). Likewise, most research to date has focused on Buddhist practices, despite the immense variety of meditation practices across different traditions, such as Christian prayers, Hinduism, Sufi mysticism or the Jewish Merkabah, among others. Expand the scope to types of meditation aside from mindfulness will be fertile ground for future research (Dahl & Davidson, 2019), analyzing similarities and differences between them.

A major barrier to comparing different types of meditation is the lack of clear consensus on a taxonomy of meditation practices (Nash & Newberg, 2013), and detecting differences may become elusive (Grossman, 2019). One of the biggest challenges in this field is to provide a unifying theory of meditation (Sedlmeier et al., 2016), which it is not an easy task: a recent review has found over three hundred types of meditation practices described in the literature (Matko & Sedlmeier, 2019).

One of the first attempts to scientifically classify the different types of meditation was the neurocognitive model proposed by Lutz et al. (2008). It differentiated between two types of meditation according to the attentional process trained: Focused Attention (FA), equivalent to concentrative or *Samatha* meditation, and Open Monitoring (OM), equivalent to receptive or *Vipassana* meditation. In FA, participants are trained to direct and sustain their attention on a selected object or ‘anchor’ (e.g., breath sensations or a candle flame). Participants not only train to sustain attention on a particular object, but also train to self-monitor the focus of their attention. When the mind wanders, practitioners are immediately invited to disengage from the distractor and redirect their attention back to the selected object. On the other hand, OM meditation trains a more distributed state of awareness; i.e., a non-reactive monitoring of one’s whole experience, rather than explicit focus on any particular object. OM practitioners are trained in ‘non-reactive meta-cognitive monitoring’ by approaching any internal or external stimulus that enter their field of consciousness with a non-judgmental, accepting attitude, regardless of its valence (i.e., positive, negative or neutral). Several studies have found that FA and OM train different cognitive and attentional processes: early stages of mindfulness training (aimed to develop FA) improve selective and executive attention, whereas the most advanced stages of the practice (during which OM is trained) improve orientation, alertness and sustained non-focused attention (Ainsworth et al., 2013; Chiesa et al., 2011; Hölzel et al., 2011; Lutz et al., 2008). Furthermore, a recent well-controlled study (Britton et al., 2018) found that an 8-week FA training involved attentional control mechanisms, while an 8-week OM only involved emotional non-reactivity mechanisms.

While the differential effects of FA and OM meditation have been widely studied in the last years, the differences with other meditation types, such as compassion or loving-kindness meditation, have been less heavily researched. Vago and Silbersweig (2012) were some of the first researchers to distinguish between concentrative (i.e., FA), receptive (i.e., OM), and ethical enhancement (i.e., compassion and loving-kindness) practices. Later evidence found that these three types of practices have different effects on attentional control and other cognitive functions (Lippelt et al., 2014), as well as different neuroanatomic correlates (Fox et al., 2016).

Similarly, a contemporary conceptualization distinguishes between three families of meditation practices according to the cognitive mechanisms they target (Dahl et al., 2015): 1) Attentional family: practices designed to train the self-regulation of attention and the present-moment meta-awareness. This family would include the practice of mindfulness (both FA and OM); 2) Constructive family: practices used to cultivate psychological well-being by developing prosocial qualities and socio-emotional skills, such as compassion, kindness, equanimity and joy; and 3) Deconstructive family: practices used to cultivate socio-cognitive skills by developing self-inquiry, enhancing insight, and dissolving the sense of self (i.e., non-dual awareness).

Certainly, these categorizations are highly theoretical. In real-world settings, it is difficult to cleanly distinguish between meditation types. In practice, most exercises and programs include a varied mixture of focused attention, open monitoring and prosocial components. In fact, different traditions suggest a 'hierarchical learning process' (Dahl & Davidson, 2019; Vago & Silbersweig, 2012), where mindfulness plays a foundational role for other meditation practices. In early stages, novice meditators typically begin by exercising concentration through the practice of FA. In later stages, meditators advance to practice of a receptive attention through OM meditations, expanding the attention focus and monitoring the consciousness itself. Developing these basic skills for calming and stabilizing the mind is a prerequisite for more advanced compassion and loving-kindness meditations, where prosocial emotions and motivations are trained.

In the present doctoral dissertation, we decided to compare the effects of mindfulness and compassion meditation, as described in the following sections.

3.3 COMPASSION MEDITATION

Compassion is considered a fundamental human value in Eastern contemplative traditions and major world religions. Yet, compassion has only begun to receive scientific interest in the past two decades (Gilbert, 2009; Goetz et al., 2010; Strauss et al., 2016). As was observed with mindfulness research, there has been an exponential growth in the number of scientific publications about compassion over the last decade (Hasenkamp, 2019). Recently, compassion has played a greater role in diverse facets of society, such as education (Wear & Zarconi, 2008), healthcare (Papadopoulos & Ali, 2016), and the economy (Molinsky et al., 2012).

From a modern evolutionary perspective, compassion is an adaptive and advantageous human quality. Compassion may be an important criterion in partner selection, as it promotes cooperative relationships and thus increases the chance for reproductive success (De Waal, 2009; Keltner, 2009). In the words of Charles Darwin (1871), "*sympathy will have been increased through natural selection; for those communities which included the greatest number of the most sympathetic members would flourish best and rear the greatest number of offspring*" (p. 130). Indeed, we are biologically programmed to take care of others, and compassion plays a significant role in our care-giving system by promoting the nurturing and protection of our offspring (Gilbert, 2019; Goetz et al., 2010). In fact, some research has found associations between attachment construction in childhood and compassion in adulthood (Gillath et al., 2005), and between parental styles and children's levels of sympathy (Eisenberg et al., 2015).

Increasing scientific interest notwithstanding, there is a lack of consensus on the definition of compassion (Goetz et al., 2010; Strauss et al., 2016). Defining compassion is challenging due to substantial overlap between compassion and other related constructs, such as empathy, sympathy, altruism, kindness and pity (Goetz et al., 2010; Strauss et al., 2016). Existing definitions of compassion differ depending on where emphasis is placed: compassion has been described as an emotion (Goetz et al., 2010), a fundamental component of the self (Neff, 2003), and a motivational system (Gilbert, 2010). However, there are also some multidimensional definitions that seek to integrate all these components (Gilbert, 2014; Jinpa, 2010; Kanov et al., 2004; Strauss et al., 2016). For instance, Strauss et al. (2016) analyzed the commonalities underlying definitions of compassion, and concluded that a comprehensive definition of compassion should integrate five core elements contributing to its ontology and phenomenology (for the self and others): 1) Awareness: to recognize suffering; 2) Universality: to understand that all human beings suffer; 3) Empathy: emotional resonance with the person who is suffering, and connection to his/her distress; 4) Acceptance: the ability to tolerate uncomfortable feelings and thoughts that appear in response to the suffering; and 5) Motivation: engaging in behaviors that help alleviate suffering. Gu et al. (2017) found preliminary empirical support for this five-factor structure.

According to Buddhist tradition, compassion (*karuna* in Pali) is one of the Four Immensurables or Four Sublime States (*Brahma Viharas* in Sanskrit), and it can be cultivated through meditation practice, among other methods (Lv et al., 2020). Buddhism suggests that compassion meditation consists of four sequential steps (Dalai Lama, 1999): 1) to wish for others and oneself to be free from animosity; 2) to wish for others and oneself to be free from mental suffering; 3) to wish for others and oneself to be free from physical suffering; and 4) to take care of oneself and others who are suffering.

After the outburst of Western research on Mindfulness-Based Programs (Goldberg et al., 2018; Gu et al., 2015), interest in the effects of Compassion-Based Programs (CBPs) has also expanded (Goetz et al., 2010; Kirby et al., 2017; Leaviss & Uttley, 2015). Several interventions have been developed to train compassion in a secular format, following the model of the MBSR. Various studies have revealed the potential benefits of CBPs in mental health and well-being (Graser & Stangier, 2018; Hofmann et al., 2011; Kirby, 2017; Seppälä et al., 2017). A meta-analysis on the effects of CBPs found moderate between-group differences on self-compassion, mindfulness, psychological distress (i.e. depression and anxiety), and well-being, even in RCTs that included an active control comparison group (Kirby et al., 2017). However, there is a lack of empirical research addressing the mechanisms of change in compassion interventions, and future research in this area is needed (Kirby et al., 2017).

The present doctoral dissertation examines Compassion Cultivation Training (CCT; Goldin & Jazaieri, 2017), an 8-week secular program developed by the Center for Compassion and Altruism Research and Education (CCARE; Stanford University). The CCT, which combines traditional Buddhist teachings with contemporary Western psychology, was designed to enhance compassion in the general population. Several studies, including randomized controlled trials (RCTs), have found that CCT leads to a variety of benefits, such as: 1) increased self-compassion, compassion for others and being the object of compassion for others (Jazaieri et al., 2013), as well as decreased the fears of compassion for self (Goldin & Jazaieri, 2017); 2) reduced stress, anxiety, and depression (Brito-Pons et al., 2018; Jazaieri et al., 2018); 3) increased positive affect and decreased negative affect (Jazaieri et al., 2014); 4) enhanced adaptive emotional regulation strategies, such as greater use of cognitive reappraisal and reduced emotion suppression (Jazaieri et al., 2014, 2018); 5) enhanced adaptive cognitive regulation processes (i.e., greater mindfulness and lesser mind wandering, worry, and rumination) (Jazaieri et al., 2014, 2015); 6) increased levels of well-being (Brito-Pons et al., 2018; Jazaieri et al., 2014); and 7) increased caring behaviors and empathic concern (Jazaieri et al., 2015). CCT appears especially beneficial for certain populations; e.g., adults experiencing chronic pain (Chapin et al., 2014) and healthcare workers (Scarlet et al., 2017). Furthermore, Goldin & Jazaieri (2017) found that some baseline participant characteristics, such as perceived stress, mindfulness, emotional regulation and self-efficacy, moderate the effects of CCT on self-compassion and fears of compassion.

3.4 DIFFERENCES BETWEEN MINDFULNESS AND COMPASSION MEDITATION

Although mindfulness and compassion practices have different philosophical and procedural underpinnings, they share the core belief that “mind training” is a way to alleviate unnecessary suffering while enhancing human flourishing and well-being. That said, there are key differences between these two practices (Jinpa, 2019): 1) being in the present moment is the core element of contemporary mindfulness practices, while compassion exercises evoke past and future scenarios; 2) whereas mindfulness practice teaches a non-judgmental attitude, compassion practice trains affective states of empathy and kindness toward oneself and others; 3) contemporary mindfulness promotes a neutral observer standpoint, while compassion emphasizes the appraisal of one’s distressing thoughts and feelings; and 4) the ethical component (understood in terms of human values) is a core element in compassion, but not necessarily in contemporary mindfulness trainings.

Despite the above-mentioned lack of clear procedural differentiation between mindfulness and compassion meditation, several studies suggest that these practices may yield different psychological effects and involve different mechanisms of change (Fox et al., 2016; Singer & Engert, 2019; Vago et al., 2019). Some pioneering projects, such as the ReSource project (Singer et al., 2016) and the Healthy Minds Initiative (2018), have begun to systematically investigate the differences between various meditation practices. Results from the ReSource project have shown that mindfulness practice (i.e., attention family) increases present-moment awareness, body awareness, and attentional performance, whereas socio-emotional practices (i.e., constructive family) reduce social stress sensitivity and increase ethical-social qualities (e.g. compassion, altruism and feelings of love) (Singer & Engert, 2019). According to self-report measures, different types of meditation have both broad and specific effects on mindfulness and compassion. For instance, Hildebrandt et al. (2017) found that present-centered awareness was increased by both attentional and constructive practices. However, only compassion meditation significantly changed socio-emotional and motivational qualities, such as non-judgmental attitude, acceptance, and (self) compassion.

Unfortunately, few studies have investigated the differences between standardized mindfulness and compassion programs. In a pioneering study, Brito-Pons et al. (2018) compared the effects of compassion and mindfulness standardized programs. They found that the two programs were equally effective in enhancing well-being, mindfulness, and compassion skills. Yet, the compassion program had a greater impact on compassion-related measures (i.e., self-compassion, empathic concern, and common humanity) than did the mindfulness program.

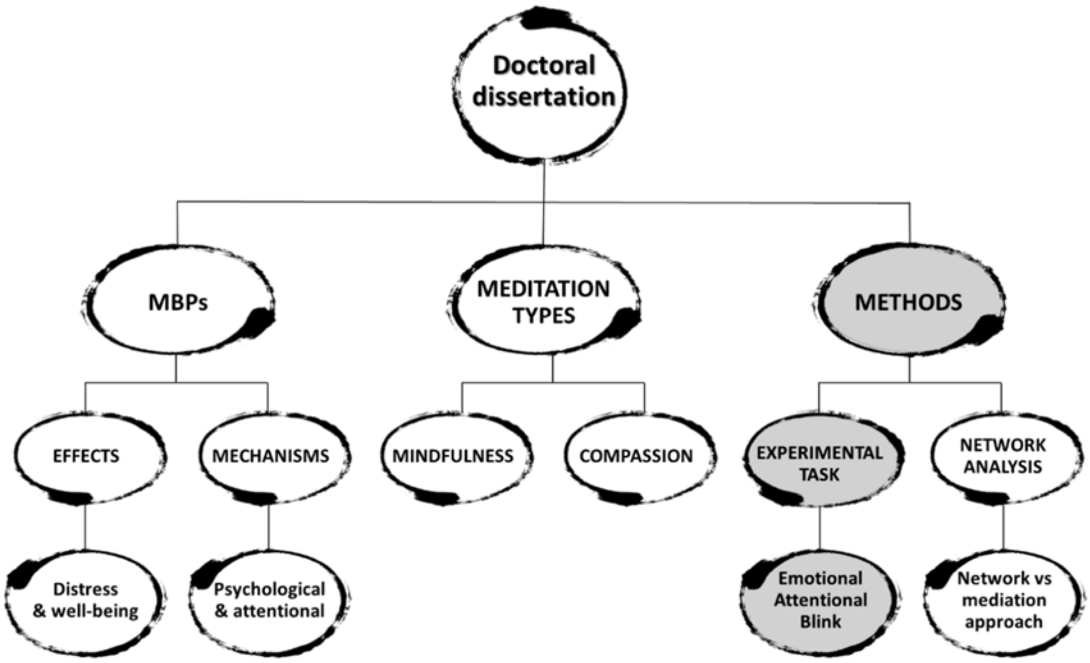
While some overlap exists between the effects of mindfulness and compassion, their mechanisms of change appear to be distinct (Desbordes et al., 2012; Fox et al., 2016). In a meta-analysis of neuroimaging studies, Fox et al. (2016) found that some brain areas are involved across different meditation types (i.e., insula, pre/supplementary motor cortex, dorsal anterior cingulate cortex, and frontopolar cortex). However, they found dissociable patterns of brain activation and deactivation across meditation types.

Furthermore, Desbordes et al. (2012) found evidence of differential changes in brain responses to emotional stimuli after mindfulness and compassion 8-week trainings. In their study, the mindfulness group exhibited a decrease in amygdala activation when viewing images of any valence (i.e. negative, positive and neutral), while the compassion group exhibited a marginal increase in amygdala activation when viewing negatively valenced images.

Taken together, these results suggest that certain effects and mechanisms are broadly shared by mindfulness and compassion interventions, while other effects are specific to each practice (Brito-Pons et al., 2018; Hildebrandt et al., 2017). Certainly, there are commonalities in these types of meditation practices, and it is not easy to draw a precise line in relation to their expected effects (Grossman, 2019). As stated above, mindfulness plays an important role as a foundation for other meditation practices and is employed as the precursor of prosocial meditation practices (Dahl & Davidson, 2019). For example, in CBPs, mindfulness is formally practiced in the early sessions as a foundation for subsequent practices (Jinpa, 2010). Similarly, contemporary MBSR, compassion is implicitly taught as an attitudinal foundation of mindfulness and is modeled by the instructors' behaviors and attitudes (Brito-Pons et al., 2018; Neff & Dahm, 2015). Further, in Buddhist traditional contexts, mindfulness practice is typically taught to prepare individuals for prosocial practices (Buddhaghosa, 2011; Kapleau, 2013).

CHAPTER 4

ATTENTIONAL BLINK

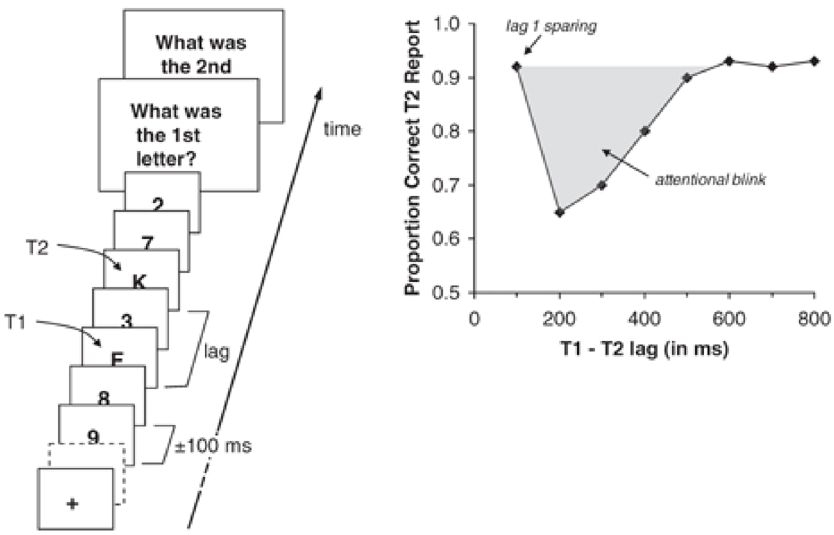


4.1 ATTENTIONAL BLINK TASK

As human attentional resources are limited, it is necessary to select information for further processing and conscious identification in short-term memory. This challenge our cognitive system faces is well-captured by the Attentional Blink paradigm (AB; Raymond et al., 1992). The AB is commonly used in research to investigate the temporal limitations of attention (Dux & Marois, 2009), framed in the Rapid Serial Visual Presentation paradigms (RSVP; Lees et al., 2018). Defined as an attentional deficit, the AB consists of a reduction in the accuracy of detecting a second target (T2) when it is presented between 200 and 500 ms after a first target (T1) (Raymond et al., 1992). The time lapsed in between the two targets is referred to as the 'refractory period'.

In the original AB paradigm, visual stimuli (i.e., letters and numbers) are briefly presented in a rapid succession in the same spatial location. Two of the items in the trial sequence are targets (T1 and T2) and the rest are distractors. A demanding task is assigned to each target: for instance, to identify the two letters (targets) embedded in the stream of numbers (distractors). The proximity of the second target relative to the first one is manipulated (i.e., T1-T2 lag). The temporal distance between the two targets is a function of the number of intervening distractors between them. Typically, the first target is correctly identified; however, the second target is poorly identified when it appears between 200 and 500 ms after the first one (see Figure 5).

Figure 5. The typical Attentional Blink task and the prototypical Attentional Blink results (Encyclopedia of the Mind, SAGE knowledge, http://dx.doi.org/10.4135/9781452257044.n28).



Multiple theoretical accounts help explain the AB effect (Dux & Marois, 2009). The findings to date are consistent with a multifactorial model of the AB (Dux & Marois, 2009), which proposes that the AB deficit arises from the high attentional demands of T1 (i.e., selection, working memory encoding, episodic registration and response selection). This demand would prevent attentional resource allocation to T2 when T1-T2 are very close (i.e., short lags). In other words, AB results from the competition for limited attentional resources between two targets (Shapiro et al., 1997), so that when many attentional resources are devoted to the processing of the first target (i.e., overinvestment of attentional resources in T1 processing), not enough attentional resources are available for the processing of the second target. This limit in attentional resources makes T2 vulnerable to distractor interference, as the cognitive system requires up to half a second (500 ms) to recover enough attentional resources to accurately identify the second target. The AB ultimately reveals the temporal limits of the deployment of selective attention (Dux & Marois, 2009), and it seems to be an index or the limited attentional capacity for selecting relevant stimuli presented among distractors.

The word ‘blink’ evokes the idea that AB may cause a ‘real blindness’ of the second target. However, studies using Event-Related Potentials (ERPs) have shown that this is not the case. Although individuals are not consciously aware of T2’s presence, the target is being processing by the brain. Several studies have found that both T1 and T2 elicit the potentials P100 (i.e., reflecting the early visual processing) and N400 (i.e., reflecting the processing of the meaning of the stimuli). However, only T1 elicits the potential P300 (i.e., reflecting the updating of working memory). In other words, when T2 is presented between 200 and 500 ms after T1, it does not elicit P300, which suggests that the missed T2 does not enter into working memory (Sergent et al., 2005; Vogel et al., 1998; Vogel & Luck, 2002). In short, T2 is processed without awareness. Thus, the AB does not prevent the stimulus from reaching our cognitive systems; rather, our failure to detect it is a problem related to access to awareness. Taken together, the classical AB deficit illustrates the temporal cost of encoding a stimulus into working memory (Olivers & Meeter, 2008), and is an index of the attentional limits of conscious perception (Dux & Marois, 2009). This makes the AB an ideal paradigm to investigate the effects of meditation, whose primary aim is to increase awareness.

4.2 ATTENTIONAL BLINK IN MEDITATORS

Despite the fact that attentional resources are limited, the AB effect does not represent an immutable bottleneck in human information processing. Several studies have shown that AB can be reduced through different manipulations of attention, such as using emotional information (McHugo et al., 2013), externally induced changes in attentional states through distracting mental activity (Olivers & Nieuwenhuis, 2005, 2006), different types of mental training, such as meditation practice (Slagter et al., 2007), or playing video games (Green & Bavelier, 2003).

To date, some studies have analyzed the effect of meditation on AB. The seminal study by Slagter et al. (2007) found that, after a three-month meditation retreat, meditators exhibited a significant reduction in the AB deficit compared to a control group, reducing the higher-order T1 processing (reflected by a reduction of the T1-elicited brain potential P3b in the EEG). These results suggested that the intensive practice of meditation improves participants' allocation of attentional resources between the first and the second target, thereby reducing the propensity to "get stuck" on the first target. These results have been replicated in subsequent studies (Slagter et al., 2009; van Leeuwen et al., 2009).

Interestingly, some studies have also found differences in the AB effect between different meditation types. Van Vugt & Slagter (2014) found smaller AB magnitude during OM compared to FA meditation, but these results were only found in expert meditators (i.e., average of 10,704 hours spent meditating). However, the effect of socio-emotional meditation, such as compassion or loving-kindness, on the AB deficit is still unclear, and current findings are mixed. Although Burgard & May (2010) found that loving-kindness meditation failed to significantly reduce the AB, May et al. (2011) found "state" differences on AB magnitude between loving-kindness meditation and a control group, but only in participants with previous meditation experience.

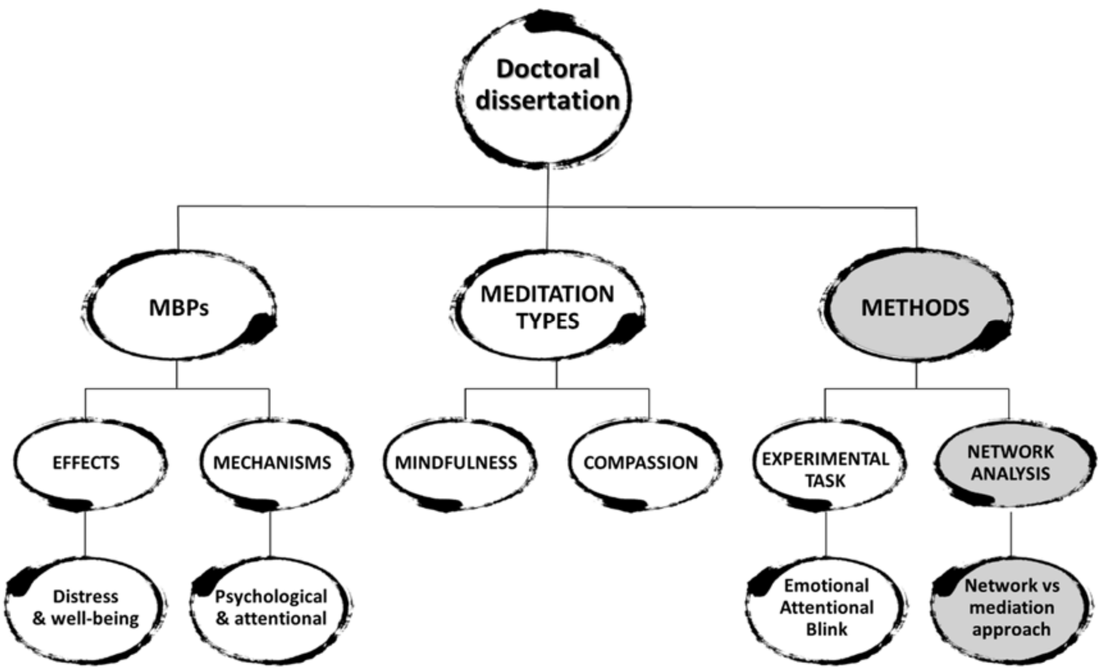
4.3 EMOTIONAL ATTENTIONAL BLINK

As previously mentioned, the AB effect appears to be modulated by the emotional relevance of T1 and T2. This phenomenon, called the Emotional Attentional Blink (EAB; McHugo et al., 2013), measures the time needed to disengage and refocus attention to emotional stimuli. Research has revealed that the AB is reduced for an emotionally-salient T2 but is enlarged for an emotionally-salient T1 (Schwabe et al., 2011). For instance, during the AB period, arousing T2 words are less susceptible to the blink deficit than neutral words (Anderson, 2005; Anderson & Phelps, 2001; De Martino et al., 2009; Keil & Ihssen, 2004). Regarding facial expressions, evidence suggests that angry and fearful T2 faces are more accurately identified than neutral T2 faces (Maratos et al., 2008; Milders et al., 2006); however, an angry T1 face renders T2 recognition more difficult (de Jong et al., 2010; Maratos, 2011). In sum, these results indicate that emotional T1 (compared to neutral) captures our attentional resources, thereby increasing the AB deficit, while emotional T2 reaches conscious awareness more easily, hence reducing the AB deficit.

To the best of our knowledge, only one prior study has analyzed the effects of mindfulness on AB using emotional stimuli (Makowski et al., 2019). This cross-sectional study, which no control group, found that dispositional mindfulness (i.e., FFMQ non-reactivity) was related to faster disengagement of attention from emotional stimuli (i.e., shorter attentional recovery after emotional distractors). This effect was paired with an increase in the probability of recognizing the negative T1, which was even more pronounced for those distractors that were followed by a T2 detection failure. The authors interpreted these results as evidence that mindfulness promotes a more flexible allocation of attention between irrelevant emotional stimuli and task-salient information. Makowski et al. (2019) urged future research to investigate the impact of MBPs on early responses to emotional stimuli via a similar task. They also recommended the use of a comparison group in order to overcome some of the limitations in previous studies. This would also enable a comparison of different meditation types and their effects on attention. That was precisely our intention in our first study, described in Chapter 7.

CHAPTER 5

NETWORK ANALYSIS

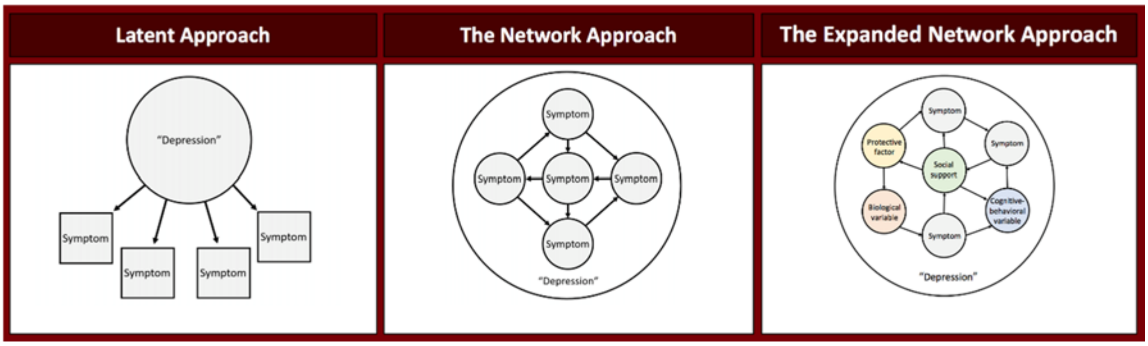


5.1 THE NETWORK APPROACH TO PSYCHOLOGY

The network approach to psychology has grown exponentially over the past decade as an alternative to traditional classification systems (Robinaugh et al., 2020). Traditional psychopathology models, both categorical and dimensional, have shown a vast array of theoretical and empirical limitations, including the assumption of local independence (i.e., the observed symptoms are conditionally independent of each other given an individual score on the latent disorder), the lack of explanation for the high comorbidity rates, the diversity of clinical presentations, and the scarce support for the identification of mechanisms and biomarkers of mental disorders (Borsboom & Cramer, 2013; Cramer et al., 2010a; Fried et al., 2017; Fried & Cramer, 2017).

In contrast to traditional diagnostic models, the network approach does not conceptualize symptoms as reflective of an underlying disorder. Rather, the network approach conceptualizes the mental disorders as a complex network of causal interactions between symptoms (Borsboom, 2017; Borsboom & Cramer, 2013; McNally, 2016). In this framework, mental disorders arise from the interactions between multiple symptoms in a network architecture (see Figure 6). Moreover, symptoms are not interchangeable indicators of mental illness, but rather, active agents in a causal network whose role depends upon their position in the network. This view of mental disorders as systems of functionally interrelated symptoms is aligned with traditional functional analyses of behavior (Hofmann et al., 2016). From this perspective, suffering from a mental disorder simply means one is 'trapped' in a network structure of self-sustaining symptoms (Borsboom, 2017). Furthermore, the network approach offers a plausible theoretical and empirical account of several psychiatric phenomena, such as the robust association patterns among symptoms, comorbidity, vicious circles, and spontaneous recovery or heterogeneity, among others (Contreras et al., 2019; McNally, 2020).

Figure 6. Categorical and dimensional traditional psychopathology models (i.e., latent approach) vs. network approach (as shown in: https://psych-networks.com/expanded-network-approach-moving-beyond-symptoms/).

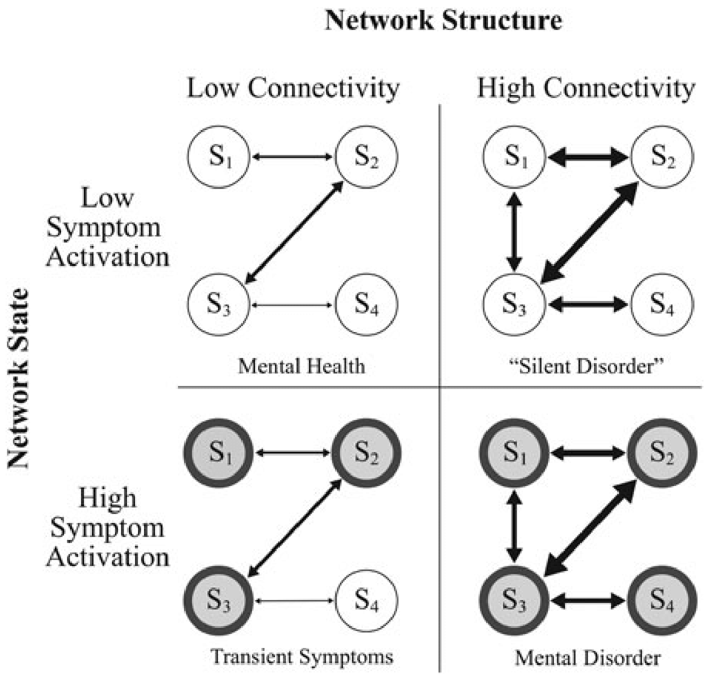


The network approach, rooted in Graph Theory (Biggs et al., 1986) and network science (Barabási, 2012), enables a mathematical analysis of the relationships between psychological variables, as well as a visual representation of these relations. In networks, psychological variables are represented by 'nodes' (i.e., circles) and the relationships between them are represented by 'edges' (i.e., lines connecting pairs of nodes). The edge thickness indicates the magnitude of the correlation between two nodes, that is, the probability of co-activation between two nodes (i.e., weighted edges). The edges can be undirected (i.e., indicating the association between two nodes) or directed (i.e., indicating the direction of the prediction). Typically, blue or green edges indicate positive associations between nodes, whereas red edges indicate negative associations. Unlike social networks, which are created by directly observing people and their relationships, psychological networks require statistical estimation.

Researchers have developed several measures to examine the local and global characteristics of psychological networks. Node centrality is one of the most relevant network metrics (Bringmann et al., 2019; Epskamp et al., 2012). Centrality is defined as how 'important' a node is within a network (i.e., how interconnected a node is with other neighboring nodes in the network). Two of the most robust centrality metrics in psychological networks are strength centrality (i.e., the sum of the absolute values of all the edge weights connecting to each node) and expected influence centrality (i.e., the sum of both positive and negative edge weights connecting to each node; Robinaugh et al., 2016). Other network metrics include node predictability (i.e., the degree to which the variance of a given node can be predicted by all other nodes in the network; Haslbeck & Waldorp, 2018), bridge centrality (i.e., nodes connecting different theoretical subnetworks within the network; Jones, 2017), or community structure (i.e., sets of nodes that cluster more strongly amongst each other than with other nodes of the network; Blanken et al., 2018), among others.

Moreover, the network approach allows us to analyze both network structure (i.e., high or low connectivity among nodes) and network states (i.e., high or low activation of the nodes) (see Figure 7). This approach is based on the hypothesis that a greater connectivity among nodes (e.g., global strength) increases the probability of a 'contagious' effect of spreading activation through the network.

Figure 7. Network structure and state (as shown in Robinaugh et al., 2020).



There are different types of cross-sectional networks (McNally, 2020), including association networks (i.e., undirected simple correlations between pairs of nodes), concentration networks (i.e., partial correlations between pairs of nodes after adjusting for the influence of all other nodes in the network), regularized partial correlation networks (i.e., concentrated network regularizing the model to shrink small partial correlations to zero), relative importance networks (i.e., directed edges signify the relative importance of a node as a predictor of another node), and Bayesian networks (i.e., directed acyclic graphs that characterize cross-sectional data as a causal system indicating the direction of probabilistic dependence, not temporal precedence). However, cross-sectional networks do not provide information on how interactions among nodes unfold over time and only depict relations between symptoms at the group, not individual, level. Accordingly, temporal time-series networks have been developed to explore whether the interactions between nodes unfold over time and for a single person (Aalbers et al., 2019; Robinaugh et al., 2020).

5.2 NETWORK APPROACH TO PSYCHOLOGICAL INTERVENTIONS

The network literature has examined whether network analysis can guide therapeutic interventions and enhance treatment efficacy. In the last years, the network approach has been used to analyze intervention-induced changes (e.g., how the association structure between nodes changes over time in response to an intervention), by a process called Network Intervention Analysis (Blanken et al., 2019). Network models have shown promise in analyzing the sequential development of direct and indirect effects of intervention-induced changes, as they highlight pathways through which an intervention produces its effects, helping to disentangle the underlying mechanisms of change.

Network analysis is also being employed in clinical practice in the form of Network-Based Interventions (Bak et al., 2016; Kroeze et al., 2017). Their aim is to target specific nodes and edges in psychological interventions. This approach regards high-centrality nodes as important therapeutic targets (Borsboom, 2017; Hofmann et al., 2016) and forecasts psychological interventions to exert some influence on the network (e.g., by deactivating nodes, inhibiting their interactions, removing external events that trigger pathological states, or promoting therapeutic cascades; Borsboom, 2017). However, the evidence base supporting central nodes as ideal therapeutic targets is still moderate (Castro et al., 2019), and other network metrics have been postulated as better markers for identifying therapeutic targets in the network (e.g., node predictability; Haslbeck & Fried, 2017).

5.3 NETWORK ANALYSIS AS AN ALTERNATIVE TO ANALYZE THE MECHANISMS OF CHANGE IN PSYCHOLOGICAL INTERVENTIONS

Despite general consensus on the need to expand research on underlying mechanisms of change in psychological interventions, the best statistical approach to analyze those mechanisms is still under debate (Hofmann et al., 2020). As mentioned in Chapter 2, mediation analysis has been the dominant approach to analyze such mechanisms of change to date (Hayes, 2009). Originally, the study of mediation was structured around the seminal article by Baron & Kenny (1986), which distinguishes between the processes of mediation and moderation. This traditional mediation approach, based on a nomothetic and cross-sectional framework, assumes that intervention changes are linear, unidirectional and contain only a few variables. However, psychological interventions usually generate a complex matrix of bi-directional relationships between multiple variables that change in dynamic ways in response to the treatment. Thus, the impact of psychological interventions cannot be reduced to a few mediators; this incorrectly assumes that psychological variables are independent from each other or that the variables form unidirectional relationships with one another. For all these reasons, the traditional mediation approach is not able to properly capture the complexity of psychological interventions (Hofmann et al., 2020). Perhaps this helps to explain why traditional mediation methods have not led to a robust science corpus of mechanisms of change.

Alternatively, mechanisms of change can be studied from a network approach, which allows a better representation of the complexity of interactions between outcomes and mechanisms involved in psychological interventions. In the present doctoral dissertation, we decided to combine both perspectives. In a first article, we used traditional analyses of variance and advanced mediation models to explore the effects and mechanisms of MBPs (Chapter 8). In two additional papers, we employed the network approach to analyze changes in relationship structures between psychological variables in mindfulness (Chapters 9) and compassion programs (Chapters 10). Our network analyses explored the effects of standardized mindfulness and compassion interventions on five sets of measures (i.e., mindfulness, compassion, well-being, psychological distress, and cognitive/emotional control) by estimating regularized partial correlation networks before and after the meditation programs. We argue that this network approach (Chapter 9 and 10), combined with traditional mediation analysis (Chapter 8) and experimental studies (i.e., emotional attentional blink task, Chapter 7), may shed light on the MBPs effects and mechanisms of change, which is necessary in the field of meditation research to move forward in evidence-based interventions (Davidson & Kaszniak, 2015; Goldberg et al., 2018; Rosenkranz et al., 2019; Van Dam et al., 2018).

5.4 LIMITATIONS IN NETWORK ANALYSIS

Although the network approach is promising, there are some methodological issues that need to be addressed (McNally, 2020; Robinaugh et al., 2020). One issue that has emerged in the past years is network replicability (Forbes et al., 2019; Jones et al., 2019). Network methods are inherently unstable, and this instability is exacerbated by using single-item nodes and small samples (DeYoung & Krueger, 2018). One of the common criticisms on the use of network analysis in psychopathology (Forbes et al., 2017a, 2017b) is that networks do not replicate as much as one might expect. Despite this controversy, however, re-analyses by Borsboom et al. (2017) demonstrated that Forbes and colleagues' critique was riddled with errors, and that main concerns surrounding replicability were reasonable addressed. To promote network robustness, the present doctoral dissertation uses large samples, designates well-validated constructs as nodes, and evaluates the stability of the MBSR and CCT networks (Epskamp et al., 2018).

Secondly, several studies have raised concerns about the use of certain centrality indices in psychological networks (Bringmann et al., 2019; Epskamp et al., 2018; Hallquist et al., 2019). Some centrality indices, especially closeness and betweenness, have shown to be unstable in cross-sectional and temporal networks (Bringmann et al., 2019; Epskamp et al., 2018). Furthermore, the assumption that central symptoms more strongly predict the onset of a disorder than less central ones is still under debate (Rodebaugh et al., 2018). For these reasons, this dissertation uses novel centrality metrics (e.g., efficiency, clustering, and bridge centrality) and robust centrality indices to mathematically handle both positive and negative edges (i.e., expected influence).

The network approach is especially valuable for exploratory analyses, as it allows us to quantify and visualize complex dependencies in the data. However, researchers must be cautious when deriving hypotheses from network theory to test in empirical research. To improve network replicability, 'confirmatory network analyses' guided by hypotheses are needed (Robinaugh et al., 2020). This confirmatory approach minimizes the risk of using network analysis with no clear theory-driven research plans (i.e., blind exploratory analyses). Moreover, most empirical network studies to date have used data that were not originally collected for network analysis (Contreras et al., 2019). This contributes to differences across studies in which 'nodes' are included in the network. To move forward, this dissertation selected a set of measures based on sound meditation theoretical models, and despite the exploratory nature of the studies, specific hypotheses were developed for both the mindfulness (Chapter 9) and compassion (Chapter 10) networks.

Although most network studies in psychology have relied on self-reported symptoms, other variables could be meaningfully incorporated into the networks (Jones et al., 2017; Letina et al., 2019; McNally, 2020), such as behavioral measures, biomarkers, clinicians' judgments, or socio-economic information (see Figure 6, the 'expanded network approach'). Similarly, most studies have employed single items as individual nodes in the network. However, there are some concerns about measurement error in network studies, especially when single Likert scales are used as nodes of the symptom severity (Krueger et al., 2010). To remedy this, constructs and composite variables can be also used as nodes in the network (Cramer et al., 2010b). Furthermore, latent variables and network models have shown to be statistically compatible (van Bork et al., 2020).

Another concern that has gained attention in network literature is whether topological overlap nodes (i.e., redundant nodes that are functionally indistinguishable from one another) can artificially increase the centrality metrics, rendering it more difficult to correctly identify the important nodes in the network (Hallquist et al., 2019; McNally, 2020). There are some preliminary methods for identifying (Jones, 2017) and addressing topological overlap (Christensen et al., 2020), although there is no clear solution to this problem and further research is needed.

CURRENT STUDY AND PUBLICATIONS

CHAPTER 6

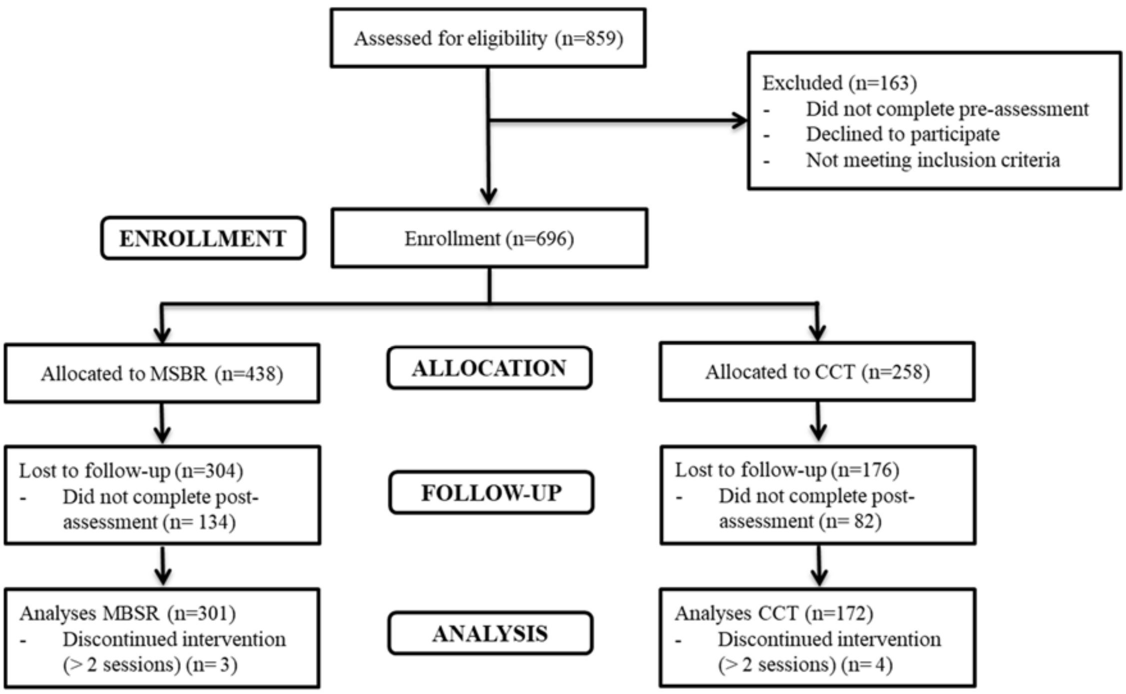
GENERAL METHOD AND PROCEDURE

6.1 PARTICIPANTS

Study recruitment occurred from April 2017 to April 2019. Participants were recruited from a university-associated research center specializing in Mindfulness and Compassion-Based Interventions. Participants were invited to join the study during the registration phase on the university's official website offering the MBSR and CCT programs. Participants then filled out a brief online screening questionnaire on demographics and inclusion/exclusion criteria. Eligible individuals received information about how to sign up for the study and gave their informed consent prior to their inclusion in the study. Ineligible individuals were not allowed to enroll in the programs. A total of 696 participants enrolled in two standardized 8-week meditation programs (MBSR and CCT).

Inclusion criteria were as follows: 1) being 18 years old or older, 2) not having any current serious psychological disorder or substance use; and 3) having attended at least 6 of the 8 sessions (i.e., 75% of the program). A precise description of the general participation attrition is presented in Figure 8, and a participation flow diagram is presented in each of the following studies. Furthermore, G*Power was used to estimate the necessary sample size in all the studies.

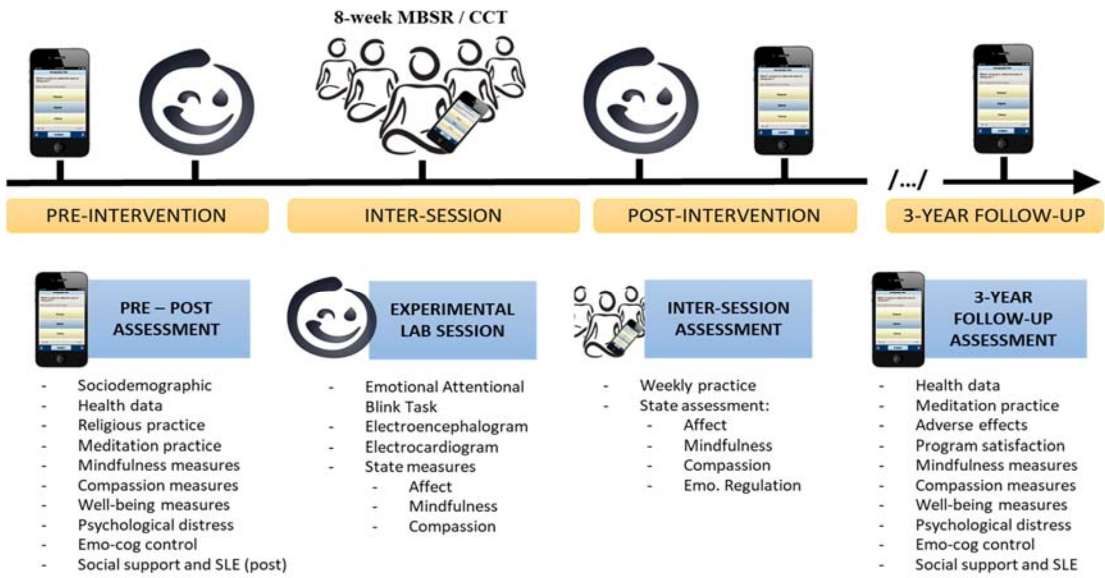
Figure 8. General participation CONSORT diagram.



6.2 PROCEDURE

The study followed a quasi-experimental design with four assessment moments (i.e., pre, inter-session, post, and 3-year follow-up), where participants were self-selected into the MBSR and CCT programs. A more detailed description of the full procedure of this doctoral dissertation is presented in Figure 9.

Figure 9. A schematic view of the procedures used in the dissertation.



The procedure included the completion of an online assessment (via Qualtrics software) during the week before the start of the program (i.e., pre-assessment) and during the week after its completion (post-assessment), as well as the completion of a 'Practice Diary' (i.e., inter-session assessment) once per week the day before each face-to-face session. When necessary, Qualtrics sent reminders to participants who had not completed the questionnaires. Some participants also volunteered to attend an experimental session (i.e. Emotional Attentional Blink task) the week before starting, and the week after finishing, their respective programs. At the end of the last assessment, session participants were debriefed on the goals of the study and were given a complimentary individualized report on their changes in the questionnaires used in the program. Finally, we are in the process of conducting an online 3-year follow-up to evaluate the long-term effects of these two standardized meditation programs. The research was approved by the university ethics committee prior to participant recruitment (Ref 2016/17-016) and was registered at ClinicalTrial.org (NCT03920241).

In the case of the Attentional Blink task, for the replication study we also recruited a control group matched by age, gender and previous meditation practice. The control group was recruited following a snowball sampling strategy, where all the participants from MBSR and CCT groups were asked to recruit other participants (friends, relatives, or acquaintances) with similar sociodemographic characteristics. The main inclusion criteria to participate in the control group was not to attend any standardized meditation training during the eight weeks of the study. Participants in the control group attended both experimental sessions with eight weeks between them[1].

6.3 PROGRAMS DESCRIPTION (MBSR AND CCT)

Mindfulness-Based Stress Reduction (MBSR) and Compassion Cultivation Training (CCT) are two 8-week evidence-based programs that offer a secular meditation training, combining insights and techniques from Western psychology and contemplative traditions. Both programs are conducted in groups of 20-30 participants and consist of weekly 2.5-hour face-to-face sessions with 30-45 minutes of daily home practices (formal and informal practices). At the end of every session, each participant received a set of pre-recorded audio files and a workbook to support their daily practices. The MBSR program was guided by three certified instructors from the Mindfulness Center at Brown University (https://www.brown.edu/public-health/mindfulness/home). The CCT program was guided by two certified instructors from the Center for Compassion and Altruism Research and Education at Stanford University (http://ccare.stanford.edu). Program fidelity was continuously monitored through regular group supervision meetings and the MBI:TAC questionnaire (Crane et al., 2013).

The MBSR (Kabat-Zinn, 2013) program aims to cultivate awareness by paying attention in the present moment to any stimulus that comes to one's own mind with acceptance and a non-judgmental disposition. During the MBSR, participants perform different mindfulness practices, including focused attention on the breath, open monitoring of awareness in body-scanning, and simple yoga postures (see Table 3).

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[1] *The studies included in this doctoral dissertation represent only a fraction of all the results derived from the whole project. We are currently preparing and submitting papers with the rest of the data.*

Table 3: Description of the MBSR modules (Koerbel & Meleo-Meyer, 2019).

MBSR protocol
Week 1 – Welcome and reflection on what has brought you to the program. Mindfulness psychoeducation based on Kabat Zinn's definition. Introduction to mindful eating (raisin meditation), standing yoga stretches, abdominal breathing and body scan meditation. Home practice: body scan and informal practice (mindful eating).
Week 2 – Attentional focus practice, standing yoga and full body scan. Discussion of the difficulties in the practice: mind wandering, sleepiness, or boredom. Nine-dots puzzle task and discussion about implicit bias and how we perceive ourselves, others and lives. Preparation for sitting meditation (attentional focus). Home practice: body scan, sitting meditation, informal practice (mindful daily activity) and Pleasant Events Calendar.
Week 3 – Lying down yoga followed by sitting meditation and walking meditation. Discussion of participant's insights encountered in formal practice (the power of being present) and in integrating mindfulness into everyday life. Review the Pleasant Events Calendar. Home practice: alternate lying down yoga with body scan, sitting meditation and informal practice (mindful of ordinary moments) and Unpleasant Events Calendar.
Week 4 – Standing yoga postures and sitting meditation with new anchors. Discussion of unwanted effects and discomfort. Review the Unpleasant Events Calendar. Home practice: body scan, sitting meditation and informal practice (awareness of automatic stress reactions).
Week 5 – Standing yoga postures and full sitting meditation. Midway reflection to take stock on what has happened during the first half of the program and identify goals for the second half. Discussion of how mindfulness helps us to recognize our automatic and conditioned patterns. Home practice: full sitting meditation practice and standing yoga sequence, informal practice (awareness of moments of reactivity and the use of STOP for new alternative reactions) and the Difficult Communications Calendar.
Week 6 – Standing yoga postures and sitting meditation with more silence. Practice intentionally bringing awareness to moments of reactivity. Mindfulness in difficult communications and interpersonal relations. Home practice: alternate sitting meditation and body scan, informal practice (awareness of communication).
Silent retreat (7.5 h.): sitting meditation, lying down yoga, walking meditation, lake meditation, talk, silent lunch, standing yoga, loving-kindness meditation, final silent sitting, and large group dialogue (dissolving silence).
Week 7 – Movement practice while scanning the body, exploring perspectives by changing seats, and sitting meditation. Discuss and review silent retreat, how mindfulness is being integrated into daily life, and how to practice in any moment. Home practice: 45 minutes practice without audio-recordings and informal practice.
Week 8 – Body scan and sitting silent meditation. Review of the program with an emphasis on daily strategies for maintaining and deepening one's practice and skills. End of the program, but the beginning of living one's life informed with mindfulness. Home practice: Continue the practice and make it your own.

By contrast, CCT (Goldin & Jazaieri, 2017) is aimed at cultivating compassion and empathy toward oneself and others. During CCT, participants practice different compassion exercises, including loving-kindness and compassion for a loved one, for oneself and toward others, as well as active compassion practices (known as *tonglen*), which involve explicit evocation of the altruistic wish to do something about others' suffering (see Table 4).

Table 4: Description of the CCT modules and session outline (Brito-Pons et al., 2019).

CCT protocol
Week 1 – Cultivating stable and focused attention through breath-focused meditation and informal practices.
Week 2 – Cultivating compassion for a loved one by learning how to identify the physical and physiological feelings of warmth, tenderness, concern, and compassion.
Week 3 – Cultivating compassion for oneself by developing self-acceptance, nonjudgment and care of oneself.
Week 4 – Cultivating loving-kindness for oneself by developing appreciation, joy, and gratitude for oneself.
Week 5 – Cultivating common humanity by recognizing our shared common humanity and the deep interconnectedness of human beings.
Week 6 – Cultivating compassion for others by progressively moving the focus from a loved one, to a neutral person, to a difficult person, and finally to all beings.
Week 7 – Cultivating active compassion by evoking the altruistic wish to alleviate others' suffering through the practice of *tonglen* ("giving and taking"), a visualization where the practitioner imagines taking away the suffering of others and giving them what is beneficial to his/her own self.
Week 8 – Integrating exercises learned throughout the program by practicing an integrated compassion meditation combining all the previous components.

Adherence to group sessions and home practices were high in both groups. In the MBSR, only 9.9% of participants missed two or more sessions. Participants in MBSR did formal practices an average of 4.67 days per week (SD = 1.63), with an average duration of 49.63 minutes each (SD = 35.50). They did informal practices on an average of 4.77 days per week (SD = 1.82), with an average duration of 41.81 minutes (SD = 58.90). Nearly 80% of MBSR participants felt 'quite/very involved' in the program, 66.5%

reported they would continue the practice 'as often or even more often' than during the program, and 98% would recommend the program to others. In the CCT group, only 7.7% of participants missed two or more sessions. CCT participants did formal practices an average of 5.25 days per week (*SD* = 1.43), with an average duration of 35.19 minutes each (*SD* = 25.48). They did informal practices an average of 5.29 days per week (*SD* = 1.66), with an average duration of 45.64 minutes each (*SD* = 45.28). Eighty-three percent of CCT participants felt 'quite/very involved' in the program, 71.4% reported they would continue the practice as often or even more often than during the program, and 96.6% would recommend the program to others.

6.4 MEASURES

In the context of psychological science, a precise assessment of meditation is essential to understand its effects. Despite the widespread use of self-reported measures, the aforementioned lack of consensus in the definition has risen some concerns about the psychometric properties of meditation measures (Grossman, 2008; Lutz et al., 2015; Van Dam et al., 2018). However, most of these psychometric concerns are not exclusive to the meditation field, and have been encountered in other areas of psychology, as is the case of anxiety or intelligence (Baumeister et al., 2007; Davidson & Dahl, 2018).

Thus, a main concern in the field of meditation is on construct validity, or the degree to which the instruments measure what they are intended to measure (Goldberg et al., 2016). The description of meditative experiences usually includes several abstract constructs and subtle experiences that are difficult to capture with standard self-reports or interviews (Petitmengin et al., 2019). Researchers have found substantial variance in the interpretation of the items and the underlying factor structure across populations. For instance, the factor structure in some mindfulness scales differs for meditators and non-meditations (Baer et al., 2008), as well as before and after an MBP (Gu et al., 2016).

Another relevant concern is that some mindfulness scales do not consistently correlate with meditation practice (Manuel et al., 2017) or are not sensitive to the group that is 'supposed to be more mindful' (Grossman & Van Dam, 2011; Leigh et al., 2005). Some mindfulness measures (e.g., FFMQ) are somehow unspecific as they do not respond selectively to mindfulness training (i.e., there are changes in both MBPs and active control conditions) (Goldberg et al., 2016). Furthermore, the correlations between different mindfulness scales may depend upon the mindfulness facets emphasized in each questionnaire (Baer et al., 2006).

There are, however, plausible explanations for these concerns and unexpected results. For example, a person who has participated in a MBP may understand and interpret the items differently than someone who has not (Baer et al., 2011). Before meditation training, individuals may not exactly know which aspects of mental states should be considered when answering items, but after the psychoeducation process of the MBPs they probably have learnt how to answer these items. Thus, the effects of MBPs on self-reported measures may be moderated by the 'quality of awareness'. Self-reported measures may depend on the limitations of introspection (i.e., first-person perspective in Francisco Varela model; Varela & Shear, 1999). Before MBP, participants may not be aware of how mindless they are, whereas after the program, awareness of one's own mind-wandering increases. However, this hypothesis has not been empirically demonstrated and, indeed, an alternative explanation could be that meditation training is ineffective (Baer, 2019). Moreover, several studies have shown an unpredicted scores decrease when using repeated administration of self-reported measures (Shrout et al., 2018).

Importantly, some mindfulness measures may be subject to demand characteristics (Grossman & Van Dam, 2011). For instance, social-desirability biases (Tracey, 2016) may be especially prevalent in self-report meditation scales, and individuals may confound the 'desire to be mindful' with actually 'being mindful'. In addition, participants learn to expect improvements in attention, equanimity, acceptance, particularly since it is difficult to blind them to the study aims and hypotheses.

Despite these concerns, commonly-used self-reported measures in meditation research have shown good psychometric properties. Overall, they provide reliable, valid and useful information to measure the effects of meditation (Baer, 2019). A review of mindfulness assessment instruments revealed strong internal consistency in most of the measures (Park et al., 2013), and several meta-analyses showed that the scores of mindfulness scales increase in response to MBPs (Quaglia et al., 2016; Visted et al., 2015), and that this increase is larger in magnitude in the MBP group than the active control conditions (Baer et al., 2019; Goldberg et al., 2018). Furthermore, the beneficial effects of meditation seem to be mediated by increases in self-reported mindfulness skills (Gu et al., 2015).

In recognition of these potential constraints, this doctoral dissertation tries to strengthen convergent validity via a multimodal approach (Lutz et al., 2015), combining subjective self-reported measures with objective behavioral-experimental and neurophysiological measures (Varela & Shear, 1999). The assessment included a set of questionnaires and experimental measures evaluating some of the main outcomes and mechanisms based on well-known psychological theories of mindfulness (Goldberg et al., 2018; Gu et al., 2015; Hölzel et al., 2011; Malinowski, 2013; Wielgosz et al., 2019) and compassion meditation (Goetz et al., 2010; Goldin & Jazaieri, 2017; Kirby et al., 2017; Strauss et al., 2016). Our assessment was designed to combine both 1) clinical-maladaptive measures with positive functioning variables; 2) trait and state measures; 3) self-report with more objective measures (such as the AB task); and 4) variables that are bio-psycho-social. The set of questionnaires we administered investigated mindfulness, compassion, well-being, psychological distress and cognitive-emotional regulation. Table 5 shows a brief description of the measures used, along with the experimental procedure. When available, Spanish validation of the questionnaires was used; otherwise, a Spanish adaptation was developed, following a double translation procedure.

Table 5: Constructs and instruments used in the dissertation.

INSTRUMENT	DESCRIPTION	MOMENT
	PRESENT-MOMENT AWARENESS	
Five-Facet Mindfulness Questionnaire-Short Form (FFMQ-SF, Bohlmeijer et al., 2011; Asensio-Martínez et al., 2019; Cebolla et al., 2012)	Measures five mindfulness skills: describing, acting with awareness, observing, non-judging of inner experience, and non-reactivity to inner experience.	Pre, post, and follow-up
Experience Questionnaire (EQ, Fresco et al., 2007; Soler et al., 2014)	Measures the ability to observe one's thoughts and feelings as temporary mind events (as opposed to reflections of the self that are necessarily true).	Pre, post, and follow-up
Multidimensional Assessment of Interoceptive Awareness (MAIA, Mehling et al., 2012)	Measures the ability to notice subtle bodily sensations via five distinct components: awareness of body sensations, emotional and attentional response to body sensations, capacity to regulate attention to the body, trusting body sensations to help in the decision making, and mind-body integration.	Pre, post, and follow-up
Non-Attachment Scale (NAS, Sahdra et al., 2010; Feliu-Soler et al., 2016)*	Assesses the absence of excessive fixation of thoughts and mental images, as well as the absence of the internal pressure to hold, change or avoid any experiences.	Pre and post
	COMPASSION	
Self-Compassion Scale-Short Form (SCS-SF, Raes et al., 2011; Garcia-Campayo et al., 2014)	Measures compassion to oneself through three components: mindfulness, self-kindness, and common humanity.	Pre, post, and follow-up
Compassion Scale (CSP, Pommier et al., 2020) *	Assesses compassion to others through four components: experiencing kindness, a sense of common humanity, mindfulness, and lessened indifference toward the suffering of others.	Pre and post
Interpersonal Reactivity Index (IRI, Davis, 1980; Fernández et al., 2011)	Measures empathy towards others. In this study, only the Empathic Concern subscale was included.	Pre, post, and follow-up

PSYCHOLOGICAL WELL-BEING		
Pemberton Happiness Index (PHI, Hervás & Vázquez, 2013)	Measures hedonic and eudaimonic components of psychological well-being. In this study, only the remembered well-being scale was included.	Pre, post, and follow-up
Satisfaction With Life Scale (SWLS, Diener et al., 1985; Vazquez et al., 2013)	Measures global life satisfaction.	Pre, post, and follow-up
Life Orientation Test–Revised (LOT-R, Scheier et al., 1994; Cano-García et al., 2015)*	Measures dispositional (or trait) optimism.	Pre and post
PSYCHOLOGICAL DISTRESS		
Depression Anxiety Stress Scales (DASS-21, Lovibond & Lovibond, 1995; Daza et al., 2002)	Assesses symptoms of depression, anxiety and stress.	Pre, post, and follow-up
COGNITIVE & EMOTIONAL REGULATION		
Ruminative Response Style (RRS, Nolen-Hoeksema & Morrow, 1991; Hervás Torres, 2008)	Measures rumination through two factors: cognitive reflection and brooding.	Pre, post, and follow-up
White Bear Suppression Inventory (WBSI, Wegner & Zanakos, 1994; Gonzalez et al., 2008)	Measures the tendency to suppress unwanted intrusive thinking.	Pre and post
Attentional Control Scale (ACS, Derryberry & Reed, 2002)	Assesses perceived ability to exercise executive control over attention.	Pre, post, and follow-up
Emotion Regulation Questionnaire (ERQ, Gross & John, 2003; Cabello et al., 2013)*	Measures two emotional regulation strategies: reappraisal and suppression.	Pre, post, and follow-up
Difficulties in Emotion Regulation Scale (DERS, Gratz & Roemer, 2004; Hervás & Salud, 2008)**	Assesses the following emotion regulation difficulties: emotional lack of control, life interference, lack of emotional attention, emotional confusion, and emotional rejection.	Pre, post, and follow-up

SOCIAL MEASURES		
Saranson Social Support Questionnaire (SSQ, Sarason et al., 1983; Martínez-López et al., 2014)**	It measures two dimensions of social support: perceived availability and satisfaction.	Pre, post, and follow-up
Life Events Checklist for *DSM-IV* (LEC-4, Gray et al., 2004) **	Screener for potentially traumatic events over the course of one's lifetime: primary support group, social environment, academic and workplace problems, housing, economic, health, legal problems, and other social-environmental problems.	Post and follow-up
STATE MEASURES		
Emotional States Scale (ESC; self-creation – pending validation)	Measures affective states, based on the Circumplex Model of Affect (Russell, 1980), combining two dimensions: valence (negative vs positive) and arousal (high vs low).	Pre-post AB task and inter-session
State Mindfulness Scale (SMS, Tanay & Bernstein, 2013)	Measures recent expression of mindful attention and awareness.	Pre-post AB task and inter-session
State Self-Compassion Scale-Brief (S-SCS-SF; self-creation – pending validation)	Adapted Self-compassion Scale that measures recent expression of self-compassion, based on the Neff (2003) model.	Pre-post AB task and inter-session
State Difficulties in Emotion Regulation Scale (S-DERS, Lavender et al., 2017)*	Measures state emotion regulation difficulties based on the Gratz & Roemer (2004) model.	Pre-post AB task and inter-session

EXPERIMENTAL SESSION		
Emotional Attentional Blink Task	A measure of temporal attentional biases to emotional information.	Pre & post program
Electroencephalogram (EEG) and electrocardiogram (EKG)**	Electrophysiological monitoring of the electrical activity of the brain and the heart.	During the AB task
Scrambled sentences task (SST; Wenzlaff & Bates, 1998)*	Measures the interpretation bias of ambiguous information.	Post AB Task
OTHER MEASURES		
Socio-demographics	Basic sociodemographic information, physical and mental health problems, substance use and disabilities.	Pre and 3-year follow-up
Religious and meditation practices	Religious and meditation practices (e.g. frequency, length, participation in retreats, etc.) and home practice (formal & informal)	Pre, inter-session, post and follow-up
Mindfulness-Based Interventions: Teaching Assessment Criteria (MBI:TAC; Crane et al., 2013)	Treatment fidelity/adherence and teacher competences.	Post and follow-up
Client Satisfaction Questionnaire-8 (CSQ-8, Attkisson & Greenfield, 2004)	Measures overall quality of the program, expectations met, needs reached, satisfaction, and quality of help received.	Post and follow-up
Meditation Adverse Effects checklist (adapted from Cebolla, Demarzo, et al., 2017)	Assesses presence of any potential adverse and unwanted effects derived from the practice of meditation.	Follow-up

Note: There were two different assessment protocols (an initial longer version and a second shortened version), and not all the measures were included in both protocols. * Measure included only in the 1st protocol; ** Measure included only in the 2nd protocol.

6.5 COMPARISON GROUP

One of the main methodological issues in meditation research relates to selecting the best comparison group (Davidson & Kaszniak, 2015; Goldberg et al., 2018; Rosenkranz et al., 2019; Van Dam et al., 2018). In clinical research, a Randomized Controlled Trial (RCT) with double-blind active control group is the gold standard experimental design. However, RCTs are not exempt from limitations. The freedom to choose one's preferred intervention is a strong predictor of therapeutic adherence and engagement (Lindhiem et al., 2014; Rennie et al., 2007). In fact, effect sizes are usually higher when participants select the treatment than when the intervention is randomly assigned (Brown et al., 2015). Further, RCTs may be subject to self-selection biases prior to randomization, whereby a segment of the relevant population removes itself from consideration (Hofmann et al., 1998). Furthermore, self-selection into a program can overestimate its potency relative to how it performs in a RCT (Lyubomirsky et al., 2011). Evaluating interventions designed to boost happiness in college students, Lyubomirsky et al. (2011) concluded that such programs "are most successful when participants know about, endorse, and commit to the intervention" (p. 391). Nevertheless, RCTs still have probative merit.

In the field of meditation research, some experts have suggested the need for moving from highly controlled RCTs to practice trials in real-word community settings (Dimidjian & Segal, 2015; Greeson & Chin, 2019), in order to determine the barriers and benefits outside of idealized academic settings. Traditional RCTs with a double-blind placebo group, originally developed in the context of biomedical research, are not always the best option for meditation research (Hoge et al., 2019). In MBPs, it is quite difficult to blind participants to their assigned condition (most could easily determine whether they have been assigned to a 'true' meditation condition; Davidson & Kaszniak, 2015). Furthermore, many control groups do not match the contextual elements of the meditation interventions (e.g. motivation and expectation effects, group effects, teacher competency, or differences between experts and novices, among others).

Therefore, one of the best control conditions to analyze the effects of meditation is to compare the impact of the MBPs to other treatment condition that matches non-specific factors of MBPs (Davidson & Kaszniak, 2015), such as the length of the intervention, the quantity and quality of home practice, participant expectations and motivation, and the expertise of the instructors. There have been some attempts to develop therapeutic comparison conditions for MBPs, such as the Health Enhancement Program (HEP; MacCoon et al., 2012). However, this HEP control group includes several therapeutic components (e.g. relaxation and aerobic exercise), and may be too therapeutic for detection of a contrast.

For all these reasons, non-inferiority trials could be a feasible alternative to compare the effects of meditation programs (Hoge et al., 2019; Streiner, 2007). In this way, a new intervention is determined to be not significantly worse than the well-establish one. This approach would also address the US Agency for Healthcare Research and Quality's concern that "special attention should be paid to developing studies that provide a more accurate assessment of the efficacy and effectiveness of meditation practices, both against standard therapies and against each other" (Ospina et al., 2007; p.208).

In the present doctoral dissertation, we have compared a well-established mindfulness program (i.e., MBSR) with a new standardized compassion program that is hypothesized to be also effective (i.e., CCT). Due to the naturalistic design of the trial, it was not feasible to randomly assign participants to either MBSR or CCT; thus, participants were not blind to the study condition. Indeed, this assignment may produce self-selection biases related to some pre-existing individual differences that could affect the results. Accordingly, we might not be able to isolate MBSR and CCT as the cause of beneficial changes observed in the respective programs. However, the potential biases arising from the lack of randomization were partially countered by the inclusion of large sample size and the use of baseline-differences as covariates in the analyses.

6.6 METHODOLOGICAL RIGOR AND QUALITY CRITERIA

Goldberg et al. (2017) carried out a systematic review analyzing the extent to which mindfulness research has increased in methodological rigor over the last years. Across 142 studies, they found that only a modest adoption of the methodological recommendations haven been incorporated in the literature. In this doctoral dissertation, we have tried to address the methodological features highlighted by Goldberg et al. (2017):

1. We have included active control conditions (standardized mindfulness vs. compassion programs), so that both groups have therapeutic intentions.

2. We have assessed a large sample size of participants to increase the statistical power and the reliability of the results.

3. According to Davidson (2010), several measures at different temporal points are necessary to differentiate the MBPs effects from those variations in individual predispositions. As such, we evaluated constructs of interests before, during and after the programs. In addition, we are currently collecting a 3-year follow-up to assess the long-term effects and maintenance of the effects of the programs.

4. Another important methodological consideration in MBPs research is to assess instructor training (Crane & Kuyken, 2019) and intervention fidelity (Crane, 2019). In the present doctoral dissertation, we have reported the level of expertise of instructors in all the studies. Importantly, the Nirakara Center is certificated to teach MBSR by the Mindfulness Center at Brown University (https://www.brown.edu/public-health/mindfulness/home) and CCT by the Center for Compassion and Altruism Research and Education at Stanford University (http://ccare.stanford.edu). All the instructors offering the program were certified and followed the original protocol. Regarding intervention fidelity, we utilized the MBI:TAC (Crane, et al., 2013) to examine the degree to which the MBPs were delivered as intended.

5. Finally, we conducted Intent-To-Treat analyses (ITT) when needed in order to make more conservative estimations of the MBPs effects. These analyses included the individuals who dropped out of the study.

In recognition of the ongoing replication crisis in psychological science (Maxwell et al., 2015), we have followed several recommendations to increase the replicability of the results. In order to improve the quality criteria of the studies and to reduce potential positive publication biases (Coronado-Montoya et al., 2016), we followed the CONSORT recommendations for nonpharmacological studies (Boutron et al., 2017; Grant et al., 2018), the Template for Intervention Description and Replication (TIDieR; Hoffmann et al., 2014) and the same template adapted to MBPs trials (Crane & Hecht, 2018):

- Pre-registration of the trial and the assumption of an open-science framework making all the data available (Foster & Deardorff, 2017).

- Acknowledgment of sources of funding and conflict of interest statements.

- Scientific background and theoretical rationale of the study in the introduction, together with specific objectives and hypotheses.

- Detailed description of the trial procedure, settings and locations of data collection.

- Detailed description of the meditation programs, reference to the standard MBPs curriculum, and instructors experience and formation.

- Detailed description of the sample, CONSORT flow diagram, eligibility criteria (inclusion/exclusion criteria), baseline characteristics, and sample size calculation.

- Detailed description of the analysis plan: Intention-To-Treat when necessary, testing assumptions, effect size, power analysis and confidence intervals.

- Discussion of the results according to the objectives and hypothesis.

- Discussion of the trial limitation, potential biases, generalizability and applicability.

- In order to prevent potential confirmation biases (Rosnow, 2002) and allegiance effects (Goldberg & Tucker, 2019), all these studies have been developed in a multidisciplinary team of researchers, combining different disciplines (psychology, mathematics, and physics) and scholars from different traditions (meditators and non-meditators).

CHAPTER 7

ATTENTIONAL PROCESSING OF EMOTIONAL INFORMATION IN MEDITATION

The Chapter 7 corresponds to the published article with the following reference:

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As mentioned in Chapter 2, theoretical and empirical models of meditation emphasize the central role of attentional control as the entry door for the rest of the mechanisms (Malinowski, 2013; Tang et al., 2015). Meditation practice seems to improve the resource allocation during early stages of the attentional processing, which in turn would improve subsequently processing (Malinowski, 2013). It has been hypothesized that the benefits of meditation on psychological distress and well-being could be partially mediated by changes in cognitive and attentional biases towards emotional information (Davis & Thompson, 2015; Ford & Shook, 2019; Garland et al., 2015a; Kiken & Shook, 2012; Vago & Nakamura, 2011), postulating as a key mechanism for understanding the effects of meditation practice. However, little is known about the processing of emotional information in meditators. Furthermore, although mindfulness and compassion meditation share common goals, empirical evidence suggests that they may produce different cognitive and attentional changes and through different mechanisms (Desbordes et al., 2012; Feldman et al., 2010). Therefore, in the first study we examined how mindfulness and compassion meditation may modulate early stages of the attentional processing of emotional information.

Considering the methodological issues of previous studies using behavioral tasks to measure the cognitive effects of meditation, some experts have called for novel cognitive tasks and variations to improve the study of the cognitive and affective mechanisms of meditation practice (Vago et al., 2019). For this reason, we developed a variant of the classical Attentional Blink task (Chapter 4) for this study using negative, positive and neutral stimuli. When comparing the sensitivity of different tasks to measure attentional biases, the AB task has shown to be particularly sensitive to attentional biases as compared to some classic tasks (e.g.., dot-probe paradigm), providing a reliable estimation of the temporal dynamics of attentional biases that others paradigms cannot offer (Sigurjónsdóttir et al., 2015). Furthermore, the AB task has shown to be reliable when used in repeated measures designs (Dale & Arnell, 2013).

After conducting a pilot study, we developed the final version of a novel variation of the AB paradigm, which allows us to not only analyze how the first target emotion captures the attentional resources, but also whether the second target emotion reaches awareness. For the AB task design, we followed the MacLean & Arnell´s (2012) methodological recommendations, as well as previous AB studies using facial expressions as targets and scrambled faces as distractors (e.g. Bach et al., 2014; Milders et al., 2006). We decided to use emotional facial expressions as targets (instead of emotional pictures) because of their critical function in social interactions and human survival (Darwin, 1872; Ekman, 1997). Furthermore, our version of the emotional AB showed a good reproducibility, being able to elicit the classical U-shaped time course observed in the standard AB task (Raymond et al., 1992).

Brief meditation trainings improve performance in the Emotional Attentional Blink

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Abstract

Objectives: To efficiently handle the continuous flow of information to which the attentional system is exposed, humans are equipped with filters like the Attentional Blink (i.e., a failure to detect a second target when it is presented between 200-500 ms after the first one). The aim of this study was to examine whether the practice of two standardized meditation programs (i.e. mindfulness and compassion) could modify the allocation of attentional resources towards emotional information.

Methods: A sample of 90 participants (43 in the mindfulness group and 47 in the compassion group) performed a variant of the Emotional Attentional Blink Task using negative, positive and neutral faces, before and after the 8-week meditation programs.

Results: Both programs significantly decreased the standard AB effect ($F_{(1.65, 145.58)} = 39.79$, $p<.001$, $\eta^2_{partial} = .31$) with only minor differences between them. Furthermore, the AB reduction after the programs varied according to the different emotional faces used ($F_{(3.10, 272.83)} = 4.44$, $p<.05$, $\eta^2_{partial} = .05$).

Conclusions: Results suggest that standardized 8-week meditation programs may significantly change early stages of emotional stimuli processing while promoting a more balanced distribution of attentional resources toward emotional information.

Keywords: Mindfulness; Compassion; Attentional Blink; Attention; Emotional Processing.

What would you think if someone told you that your attentional system is functionally "blind" immediately after processing a stimulus? We all know that our eyes automatically blink several times per minute, but it is less known that the attentional system also "blinks", suffering spontaneous "blackouts" when it shifts its focus from one stimulus to another. This attentional blackout is known as the Attentional Blink effect (AB; Raymond et al., 1992), which has been repeatedly found in studies investigating the temporal limitations of attention. The AB effect is an attentional deficit consisting of a reduction in the processing accuracy for a second target (T2), when it is presented between 200 and 500 ms after a first target (T1).

Despite the fact that attentional resources are limited, the AB does not capture an immutable bottleneck in human information processing, and it can be reduced through a variety of attention manipulations (Olivers & Nieuwenhuis, 2005). One of the most empirically supported methods to enhance attention is the practice of meditation (Chiesa et al., 2011). The seminal study of Slagter et al. (2007) found that, after a three-month meditation retreat, meditators exhibited a significant reduction in the AB deficit compared to a control group. These results suggested that the intensive practice of meditation improved participants' allocation of attentional resources between the first and the second target, thus reducing the propensity to "get stuck" on the first target.

Theoretical and empirical models of meditation emphasize the central role of attentional control as the entry door for the rest of the acting mechanisms (Malinowski, 2013; Tang et al., 2015). Studies using different methodologies seem to indicate that Mindfulness-Based Programs (MBPs) increase the efficiency of attentional functions by improving the resource allocation flexibility (Malinowski, 2013; Moore et al., 2012). MBPs have also been found to be an effective treatment for mood disorders (Kuyken et al., 2016) and is possible that the benefits of these programs are mediated, at least partially, by improvements in attention. It has been found that both a reduced attentional capacity (Rock et al., 2014) and attentional bias towards negative information (Peckham et al., 2010; Pergamin-Hight et al., 2015), are associated with emotional distress, including common mental problems like depression and anxiety. It could be possible that the positive effects of MBPs on these disorders may be partially due to reductions in cognitive and attentional biases towards emotional information (Kiken & Shook, 2012). However, it is unclear whether and how meditation practice modulates the attentional processing of emotional information.

On one hand, some studies have found that meditators seem to favor attentional responses towards positive information as compared to negative information (Erisman & Roemer, 2010; Pavlov et al., 2015). On the other hand, several studies have indicated that meditation may reduce interference from affective information, finding no differences in the attentional processing of the different emotions (Blanco et al., 2020; Brown et al., 2012; Ortner et al., 2007). Yet, there is scarce research on how different types of meditation practices may differ in regard to cognitive and emotional changes. Most of the experimental studies in this field (Ainsworth et al., 2013; Chiesa et al., 2011) have been conducted with individuals practicing some variations of meditation that capitalize their intervention in the improvement of attention (i.e. focused attention and open monitoring). On the other hand, psychological changes associated with meditation practices that capitalize on emotional changes (i.e. compassion and loving-kindness meditation) have been scarcely investigated (Desbordes et al., 2012).

It has been found that the AB effect is modulated by the emotional relevance of T1 and T2. Specifically, research has revealed that the AB is reduced for emotional T2 while is prolonged for emotional T1 (Schwabe et al., 2011). This phenomenon, which has been called Emotional Attentional Blink (EAB; McHugo et al., 2013), measures the time needed to disengage and refocus attention to emotional stimuli. For instance, the AB literature have shown that angry and fearful T2 faces are better identified that neutral T2 (Maratos et al., 2008; Milders et al., 2006). Furthermore, angry T1 reduces T2 recognition (de Jong et al., 2010; Maratos, 2011). As far as we know, only a recent cross-sectional study, with no control group, has analyzed the effects of mindfulness on AB using emotional stimuli (Makowski et al., 2019), finding that dispositional mindfulness was related to faster disengagement of attention from emotional stimuli. In research on meditation the issue of control groups is particularly important due to the difficulties to control possible motivational effects (Davidson & Kaszniak, 2015). Thus, the strategy of using two standardized meditation programs, with a similar format and duration but with remarkable differences in contents, seems to be an adequate methodological strategy to reduce some potential cofounding effects of motivation (or lack of), task demands or differences between novices and experts (Malinowski, 2013; Wallace & Shapiro, 2006).

The aim of the present study was to examine whether the practice of an attentional meditation program (i.e. mindfulness-based stress reduction - MBSR) or a socio-emotional meditation program (i.e. compassion cultivation training - CCT), following the classification of meditation practices suggested by Dahl et al. (2015), could modify the distribution of attentional resources towards emotional information, measured by an AB paradigm using emotional stimuli. Despite the lack of specific evidence from previous studies on emotional AB and on the different meditation programs, based on previous literature analyzing differences and similarities between mindfulness and compassion programs (Brito-Pons et al., 2018), the following hypotheses were set up: 1) both meditation programs would reduce the AB deficit, and 2) the AB reduction would be different for each emotion. Also, as there is evidence of differential changes in brain responses to emotional stimuli after mindfulness and compassion 8-week trainings (Desbordes et al., 2012), a third hypothesis stated that there would be differences between the two training groups in the attentional processing of emotional information (i.e. T1-T2 combinations). Specifically, it was hypothesized that whereas the mindfulness program would improve the AB for all types of emotions, the compassion program would show a specific advantage in the AB for negative stimuli, as in compassion meditation attention is trained specifically to focus on one's and others' suffering with the purpose of alleviating it (Jazaieri et al., 2013).

Method

Participants

A sample of 90 participants (43 in MBSR and 47 in CCT) were recruited in a university associated research center specialized in mindfulness and compassion-based programs (see Supplementary Figure 1). Participants' mean age was 46.31 (*S.D.*=10.63) and 74.4% were women. No significant differences between groups were found in sociodemographic variables, except in age ($t_{(88)} = -2.88$, $p<.05$; MBSR average age = 43.10; CCT average age = 49.27). No significant differences between groups were found in the mean number of years of previous meditation practice ($t_{(9.14)} = 1.56$, $p>.05$). Inclusion criteria were as follows: (1) normal or corrected-to-normal vision; (2) 18 years of age or more; (3) not having any current serious psychological disorder or substance use. Sample size calculation was conducted using with G*Power (v. 3.0.10) to test the difference between two independent group means using a two-tailed test, a small effect size of 0.25 (Brito-Pons et al., 2018), and an alpha of .05. To achieve a power of 0.90, the analysis showed that a total sample of 88 participants would be required.

Procedure

The study followed a pre-post design, and participants were blind to the aims of the study. Participants were invited to take part in the study when they registered on the official website offering the MBSR and CCT programs. After being recruited and having filled out a brief online screening questionnaire, participants attended the experimental session (i.e. emotional AB) the week before starting and the week after finishing their respective programs. Participants gave their informed consent prior to their inclusion in the study. Furthermore, the study was approved by the university ethics committee prior to participant recruitment and was registered at ClinicalTrial.org (NCT03920241).

Programs description (MBSR and CCT)

MBSR and CCT are 8-week standardized programs, consisting of 2.5-hour of face-to-face sessions, 30-45 minutes of daily home formal and informal practices, conducted in groups of 20-30 participants. The MBSR program was applied by three certificated instructors by the University of Massachusetts Centre for Mindfulness (https://www.umassmed.edu/cfm/) and the CCT programs were taught by two teachers certified by the Centre for Compassion and Altruism Research and Education at Stanford University (http://ccare.stanford.edu/). During the MBSR (Kabat-Zinn, 1990), different mindfulness practices are performed, including focused attention on the breath, open monitoring of awareness in body-scanning, prosocial meditation and gentle *hatha yoga*. During the CCT (Jinpa, 2010), different compassion practices are performed, including loving kindness and compassion for a loved one, for oneself and toward others. It also included active compassion practices (*tonglen*), which involve explicit evocation of the altruistic wish to do something about others' suffering.

Design

The experiment followed a 3 (T1 emotion: angry, happy, and neutral) x 3 (T2 emotion: angry, happy and neutral) x 3 (T1-T2 lag: 2, 4 and 6) x 2 (group: MBSR and CCT) x 2 (Time: pre and post intervention) factorial design. Dependent variable for all analyses was T2 accuracy (i.e. emotion identification) upon having correctly identified T1 emotion, in the Emotional AB, following the recommendations by Stein et al. (2009). The AB task has shown to be reliable when used in repeated measures designs (Dale & Arnell, 2013).

Measures

Stimuli and Apparatus

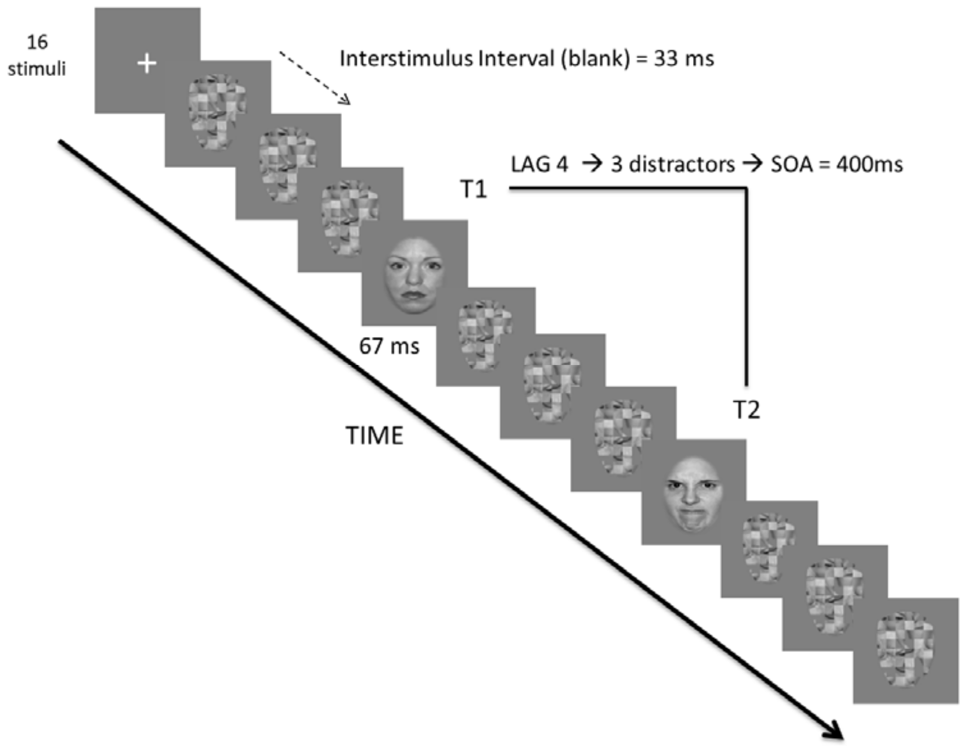
The experiment was programmed in E-prime (Psychology Software Tools, Inc., Pittsburgh, PA). Target stimuli were 48 pictures of human faces (neutral, happy, and angry, 16 each), from 8 male and 8 female individuals, selected from the NimStim Face Stimulus Set (Tottenham et al., 2009). Distractor stimuli were constructed, using Photoshop CS.6 (Adobe Systems, San Jose, CA) by cutting these 48 pictures into squares of 50 x 50 pixels, combining them randomly and applying the same background mask. All stimuli were presented on a gray background with a size of 506 x 650 pixels.

Emotional Attentional Blink task

Participants engaged in a variant of the Emotional Attentional Blink Task (see Supplementary Materials for more details) in which they had to identify the emotion(s) of the face(s) presented at T1 and T2, via a corresponding keyboard key, at the end of each trial. Each trial concluded with two questions measuring accuracy of attention: “Which emotion did you see in the first/second face?” with four response alternatives: “neutral”, “angry”, “happy” or “I haven’t seen any faces”. The response keys were balanced across participants (i.e., z, x, n, m).

Figure 1 shows the experimental trial sequence. Each trial began with a fixation cross presented for 1000 ms, followed by a rapid serial visual presentation of 16 stimuli (Experimental trials = 14 distractors + 2 targets; Control trials = 15 distractors + 1 target). After the T2 stimulus, 4 or 5 more distractors were shown. The stimuli were presented for 67 ms each, with 33 ms inter-stimulus intervals (blank). All combinations of emotions were presented equally often and target stimuli were randomly sampled.

Figure 1. Experimental trial sequence. The figure shows an example of a trial with neutral T1 and angry T2 with three intervening distractors (SOA = 400 ms). In each trial, 16 stimuli were presented at the center of the screen, preceded by a 1,000 ms fixation cross. Stimulus duration was 67 ms, followed by a 33 ms blank, resulting in 100 ms between different items. Distractors were scrambled faces from the same set of faces. Within the sequence of stimuli, in each trial, there were two faces (target 1 and 2) and participants were asked to identify the particular emotions depicted by each one at the end of the trial. The interval between T1 and T2 (i.e. lag) varied from 2, 4 and 6 temporal positions (i.e. from 200, 400 and 600 ms).



The task consisted of 5 practice trials, followed by 6 blocks of 66 trials per block. Participants completed 396 total trials, 20% of which were single-target control trials (i.e. T1 absent) and 80% were double-target experimental trials (i.e., T1 and T2 presence). Each cell of the design (3 T1 x 3 T2 x 3 Lags = 27 trial types) was presented 12 times. In experimental trials, one-third of the trials was configured with one distractor between the targets (Lag = 2; SOA = 200 ms), one-third was configured with three distractors between the targets (Lag = 4; SOA = 400 ms), and one-third was configured with five distractors between the targets (Lag = 6; SOA = 600 ms). Trial types were randomly intermixed and T1-T2 male/female face combinations were also varied randomly across participants. T1 stimuli were equally and randomly presented at serial positions 9 or 10 for short lag trials, 7 or 8 for medium lag trials, and 5 or 6 for long lag trials. All T2 stimuli were equally and randomly presented at serial positions 11 or 12. After the presentation of the T2 stimulus, 4 or 5 more distractors were shown. This variation of the positions of T1 and T2 in the sequence was made to make the task less predictable and to break monotony. To maintain consistency, T1 stimuli were randomly presented at the same serial positions in both the control and experimental trials. To diminish fatigue, participants were given a 1-min break between every two blocks (i.e. 132 trials). The task took approximately 40 minutes.

Data Analyses

Data on T2 accuracy, given accurate identification of T1, were subjected to a 3 (T1-T2 Lag: 2, 4, 6) x 3 (T1 Emotion: neutral, happy, angry) x 3 (T2 Emotion: neutral, happy, angry) x 2 (Group: MBSR vs CCT) x 2 (Time: pre-post-program) mixed ANOVA (see Supplementary Table 1 for means and standard deviations). Group was a between-subject factor and all the rest were with-subject factors. For all the analyses: (a) ANOVA assumptions were tested at baseline, using Greenhouse-Geisser correction when the assumption of sphericity was violated; (b) pairwise Bonferroni corrected comparisons were used for post-hoc analysis; (c) partial eta-squared effect sizes and power analysis (i.e., 1-β) were carried out; and (d) all statistical tests were two-sided. SPSS 25 was used for all analyses, which were conducted only for data from participants who completed both pre- and post-assessments having attended at least 6 of the 8 sessions (i.e., 75% of the program). The control trials were used to check incorrect response tendencies, which led to eliminate two participants, one in each group, with a false alarm rate higher than 50% or T1 accuracy lower than 50%. Furthermore, a task reproducibility analysis was carried out to test if our variant of the AB task fulfilled the basic assumptions of the original task (see Supplementary Figure 2).

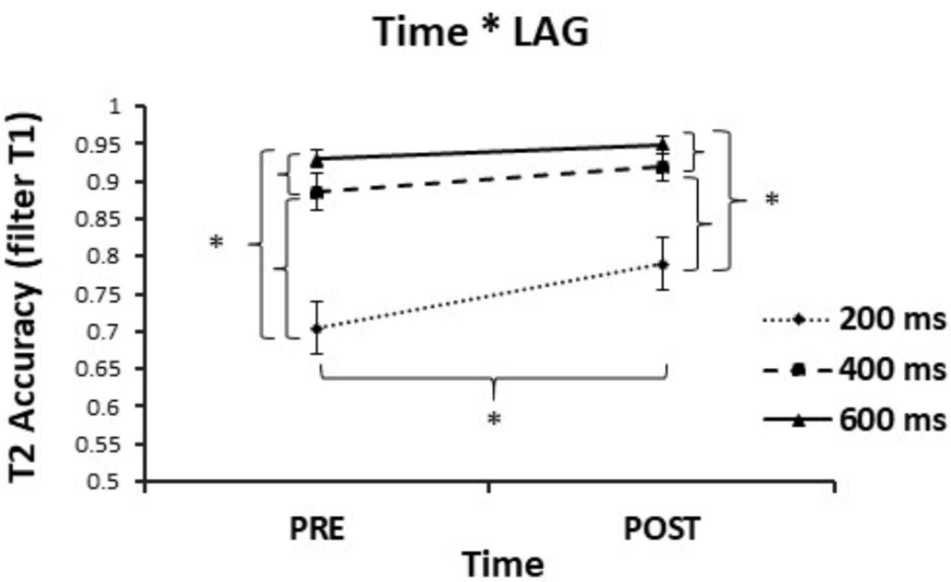
Three indexes were calculated to test each of the three hypotheses. For the first hypothesis (i.e., AB reduction after the meditation programs) a significant Lag x Time interaction would indicate a lag-dependent or "*standard* AB effect." For the second hypothesis (i.e., AB reduction would be different for each emotion) a significant T2 emotion x Lag x Time interaction would indicate an "*emotional* AB effect". Finally, for the third hypothesis (i.e., AB differences between mindfulness and compassion programs depending on lags and T1-T2 emotion combinations) a significant T1 Emotion x T2

Emotion x Lag x Time x Group interaction would be indicative of a "*complex emotional* AB effect" based on the variables included in the study. The data of the study are available at https://github.com/nirakara-lab/AB-MEDITATORS.git.

Results

Firstly, a significant Lag x Time interaction was found ($F_{(1.65, 145.58)} = 39.79$, $p<.001$, $\eta^2_{partial} = .31$; $1-\beta = 1.00$), supporting the first hypothesis (i.e. lag-dependent effect): the standard AB deficit was significantly reduced after meditation programs. Pairwise Bonferroni corrected comparisons indicated that T2 accuracy significantly increased after the programs for the three lags (see Fig. 2): 200 ms (95% CI = -.10, -.07); 400 ms (95% CI = -.05, -.02); and 600 ms (95% CI = -.03, -.02). However, there was no Lag x Time x Group interaction ($F_{(1.65, 145.58)} = .97$, $p > .05$), revealing a similar lag-dependent effect in both programs.

Figure 2. Lag-dependent effect or "standard AB effect". Average T2 emotion identification accuracy (given accurate identification of T1) is presented separately for each lag between targets (i.e. 200, 400, and 600 ms), before and after both meditation programs. The error bars represent the standard error.

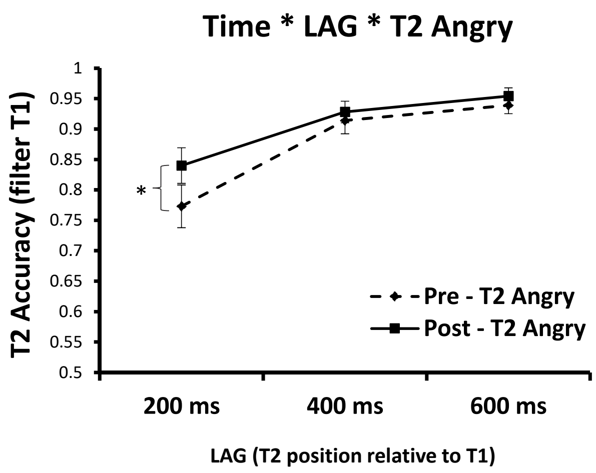


Secondly, a significant T2 emotion x Lag x Time interaction was found ($F_{(3.10, 272.83)} = 4.44$, $p<.05$, $\eta^2_{partial} = .05$; $1-\beta = .88$), supporting the second hypothesis (i.e., Lag as a function of T2 emotion): the emotional AB effect significantly changed after the meditation programs. Pairwise Bonferroni-corrected comparisons revealed that this AB reduction after the meditation programs depends on the emotions processed: (1) in the case of angry T2, there was only a significant improvement for the shortest lag (95% CI = -.09, -.04); (2) for happy T2 there was a significant improvement for short (95% CI = -.08, -.04) and medium lags (95% CI = -.06, -.02); and (3) in the case of neutral T2, significant improvements on accuracy were observed in the three lags (see Figure 3): 200 ms (95% CI = -.16, -.09); 400 ms (95% CI = -.06, -.02); and 600 ms (95% CI = -.05, -.02). The Lag x T2 Emotion x Time x Group interaction ($F_{(3.10, 272.83)} = 1.47$, $p >.05$) was not significant.

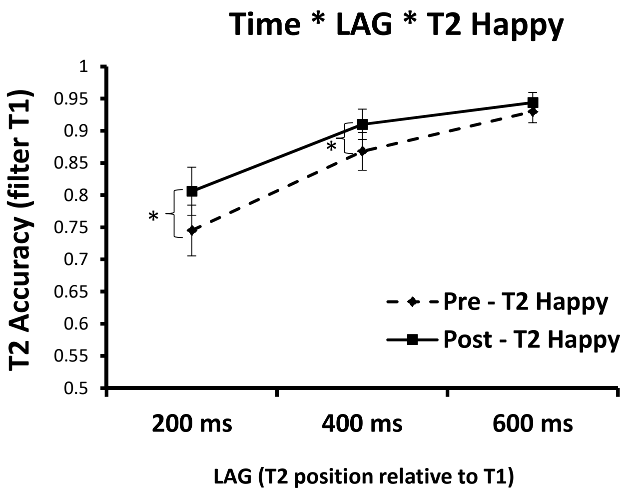
Thirdly, the full interaction Lag x T2 Emotion x T1 Emotion x Time x Group ($F_{(6.48, 570.17)} = 1.27$, $p >.05$) was not significant. However, considering that T1 emotion did not show a significant effect on T2 accuracy after the meditation programs, we decided to delete the T1 Emotion factor. A series of 3 (T2 emotion: angry, happy and neutral) x 3 (T1-T2 Lag: 2, 4, and 6) x 2 (Group: MBSR and CCT) x 2 (Time: pre and post) mixed ANOVA was carried out for every T1 emotion. This analysis revealed some marginal differences between MBSR and CCT programs in the processing of emotional stimuli, specifically after an angry T1 (see Supplementary Materials).

Figure 3. Lag as a function of T2 emotion. Average T2 emotion identification accuracy (given accurate identification of T1) for the T2 angry faces (Panel A), for the T2 happy faces (Panel B) and for T2 neutral faces (Panel C). Results are presented separately for pre- and post-meditation programs for each interval between targets (i.e. 200, 400 and 600 ms). The error bars represent the standard error.

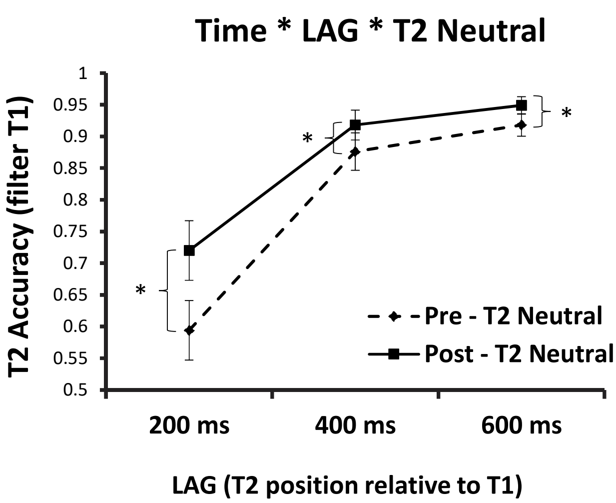
Panel A



Panel B



Panel C



Discussion

The general aim of the study was to examine whether the practice of two standardized meditation programs could change the distribution of temporal attentional resources towards emotional information, using a variant of the emotional attentional blink task.

Our first hypothesis, which stated that both meditation programs would reduce the AB deficit, was supported. The analysis of lag-dependent effect indicated that the standard AB was significantly reduced after the meditation programs. Our results corroborate previous studies showing a reduction in AB magnitude in meditators (Slagter et al., 2007; van Leeuwen et al., 2009), while extending these findings to brief meditation trainings. The blink reduction found by Slagter et al. (2007) was reported after a 3-month intensive open monitoring meditation retreat, which involved 10-12 hours of meditation practice per day. In our study, the blink reduction was produced with 8-week meditation programs with 30-45 minutes of daily practice. A plausible explanation of this effect is that meditation practice would increase the flexibility of allocation of attentional resources by reducing the attention captured by an emotional T1 (Most & Jungé, 2008) and modulating early stages of stimulus processing (Malinowski, 2013; Moore et al., 2012). Meditation might enhance early automatic attentional processes by promoting a faster disengagement of attentional resources from emotional stimuli. As the AB effect seems to be due to an overinvestment of attentional resources in stimulus processing, it could be counteracted by promoting a more distributed state of mind that is achieved when participants are concurrently engaged in task-irrelevant mental activity, such as listening music or thinking about their holidays (Olivers & Nieuwenhuis, 2005, 2006). A similar effect could be achieved by formal brief meditation trainings.

How do attended stimuli reach the level of conscious perception? This fundamental question has been previously addressed using the AB paradigm (Asplund et al., 2014). Most theories suggest that the AB deficit illustrates the temporal cost of encoding a stimulus into working memory (Olivers & Meeter, 2008), being an index of the attentional limits of conscious perception (Dux & Marois, 2009). In this respect, meditation has been described as the ability to maintain the object of attention in working memory (Dreyfus, 2011), thereby increasing the awareness of the present moment. Although attention and conscious perception are distinct, whilst related, phenomena, literature on cognitive processes in meditation has focused on the attentional effects of meditation rather than on its effects on conscious perception (Schofield et al., 2015). Our results are consistent with the hypothesis that meditation facilitates greater awareness of one's sensory and perceptual experience (Lutz et al., 2008), increasing the conscious identification of very rapidly presented emotional stimuli. According to the findings of the current study, a simplified view of meditation as a tool to merely improve attention may not do justice to the nuances of the possible effects of meditation on other processes as, for instance, on the conscious identification of emotional information.

The second hypothesis stated that the AB reduction after both meditation programs would differ for each emotion. The analysis of lags as a function of T2 emotion supported this hypothesis, indicating that the Emotional AB effect significantly changed after the meditation programs. After completing the 8-week trainings, both meditation programs significantly increased the accuracy to detect emotional faces presented at T2. More specifically, there were significant improvements for angry faces in the shortest lag (200 ms), for happy faces in short and medium lags, and for neutral faces in the three lags.

In a previous study using similar paradigm, Makowski et al. (2019) found that dispositional mindfulness was associated with a shorter attentional recovery after negative stimuli. The present results showed that an 8-week meditation training is also able to reduce the blink for positive and neutral stimuli. The blink reduction for neutral stimuli could indicate that meditation training has an overall effect of enhancing attention and conscious awareness, even after presenting an emotional T1. In fact, the neutral T2 for the short lag – the most challenging trial condition – was precisely the condition showing greater blink reduction after the meditation programs (i.e. greater accuracy increase for neutral stimuli), reaching the performance of negative and positive stimuli before the program (see Figure 3).

The human attentional system seems to be biologically prepared to prioritize the processing of negative stimuli of our environment to guarantee our survival (Savage et al., 2013). Perhaps due to this intrinsic predisposition, in our study, improvements of attention for angry faces were more limited than for happy and neutral faces. Yet, interestingly, in the case of angry faces the only significant improvement was found in the challenging 200 ms condition (see Figure 3). In general, the results suggest that the cognitive system has a greater margin of benefit from attentional training for positive faces (were improvement were for short and medium lags), and even greater for neutral faces (where improvements were found for all lags) than for negative faces. This result could be interpreted as if meditation training helped to balance out the salience of negative stimuli in the cognitive system by promoting a less biased attention (i.e., improvements in the processing of positive and neutral T2 stimuli by reducing the interference from affective information in T1).

These results highlight the potential effects of meditation practice for the modification of negative cognitive biases (Kiken & Shook, 2012). A growing body of studies supports the efficacy of meditation programs for reducing emotional disorders (Goyal et al., 2014; Kuyken et al., 2016). However, the mechanisms underlying these emotional benefits are still unknown. If these results are confirmed in further studies, they might indicate that meditation practice contributes to balance out the negative bias by improving the processing of positive and neutral stimuli which, in turn, might reduce the symptoms associated with emotional distress. Future research could explore to what extent these automatic attentional changes towards emotional stimuli may interact with conscious strategies to redirect attention (Saunders et al., 2016).

Based on meditation literature and theoretical models rooted in Buddhist Psychology (e.g. Wallace & Shapiro, 2006), improvements in the balance of processing emotional information could be interpreted as an indicator of equanimity. Equanimity can be defined as an even-minded mental state towards all experiences, regardless of their hedonic tone (Desbordes et al., 2015; Hadash et al., 2016). Thus, equanimity would allow a less biased conscious awareness, facilitating an attitude of non-attachment. Therefore, equanimity is associated with a change in the experience perceived and could be understood as an emotional regulation strategy, promoting a faster recovering from emotional stimulation (Desbordes et al., 2015). The present results seem to indicate that participants formally trained in brief, structured meditation programs achieve a higher equanimity (here operationalized by a faster disengagement from emotional information after the programs and a more balanced distribution of attention to emotional information by improving mainly the processing of positive and neutral stimuli). Considering the limitations of self-report measures to quantify equanimity (Desbordes et al., 2015), the emotional variant of the AB task used in this study could perhaps be considered as an indirect measure of equanimity, whose validity should be addressed in future studies.

Finally, the third hypothesis stated that whereas the mindfulness program would improve the AB for all types of emotions, the compassion program would show a specific advantage in the AB for negative stimuli. The results did not support this hypothesis. Interestingly, despite the fact that MBSR is an attentional meditation program and the CCT is a socio-emotional program, both programs reduced similarly, although marginally, the blink effect towards emotional information and small differences emerged between programs (see Supplementary materials). Desbordes et al. (2012) found an overall decrease in amygdala activation when presenting images of any valence (i.e. negative, positive and neutral) in a MBRS group and a non-significant trend of increases in amygdala activation in response to negative images in a compassion training group. Based on these results, one possible interpretation of the lack of supporting evidence for the third hypothesis of the present study is that longer practice is needed for differences in attentional processing of emotional information to emerge.

One alternative explanation of the overall results of the study would be that, as participants did the task twice (pre-post meditation program), target accuracy might have become easier as a result of practice. However, a general practice effect cannot easily explain the selective improvement in T2 accuracy in short lag between groups after an Angry T1 or a Happy T1 (see Supplementary Materials). Furthermore, as we pointed out in the method, the AB task has shown to be stable when used in repeated measures designs (Dale & Arnell, 2013). Future studies might well include a third control group without meditation training to clarify if the improvements after the program are due to the practice effect. Another possible explanation is that participants became better at predicting the moment at which a target would appear. Yet, to minimize this possibility, the T1 and T2 position was varied in the sequence of presentations to make less predictable the target onset.

While mindfulness meditation has been associated with an AB reduction in previous studies (Slagter et al., 2007; van Vugt & Slagter, 2014), the cognitive and attentional effects of compassion meditation, and its action mechanisms, have been scarcely investigated. Despite the focus of compassion training on emotions, attention is also trained in this approach (i.e., practitioners focus their attention on one’s and others’ suffering, and when their attention inevitably wanders, they must bring it back). Thus, compassion meditation may share some mechanisms with mindfulness meditation, which may explain the similarities in the improvements in AB found in both programs. In previous studies using the standard AB it has been found that an 8-week socio-emotional meditation (i.e., loving-kindness) did not produce a significant reduction in AB effect after training (May et al., 2011). This inconsistency of results may be due to the fact that in the present study an emotional variant of AB was used, instead of the standard AB task, which can facilitate the assessment of attentional changes produced by socio-emotional meditation.

Strengths, Limitations and Future Research Directions

Our study shows some strengths. Firstly, it is one of the few studies comparing cognitive mechanisms between different meditation programs. Meditation should not be considered as a unitary technique, and research seems to suggest that the action mechanism and outcomes of different meditation types may be different. The present study may contribute to understanding the effects of different standardized meditation programs, which is something needed in the field. Secondly, we have analyzed two well-controlled standardized meditation trainings, taught by certified instructors, which adds control of external variables that may affect the training method. Thirdly, a novel variation of the AB paradigms was designed, which allows not only to analyze how the T1 emotion captures the attentional resources, but also how the T2 emotions reach awareness. Furthermore, our version of the emotional AB showed a good reproducibility, being able to elicit the classical U-shaped time course observed in the standard AB task. For the attentional blink task design, we followed the methodological recommendations proposed by MacLean & Arnell (MacLean & Arnell, 2012), as well as previous emotional AB task using facial expressions (Bach et al., 2014; Milders et al., 2006). For instance, T2 accuracy was used, having correctly identified T1 emotion, which is a robust and conservative measure of the AB effect.

The study has also some limitations. As it is common to most studies on meditation, blinding participants to the nature of the study and random allocation is difficult to achieve (Vago et al., 2019; Van Dam et al., 2018). Yet, the strategy of comparing two standardized active interventions may reduce some potential confounding effects of motivation, demand characteristics or differences between experts and novices (Malinowski, 2013; Wallace & Shapiro, 2006). Finally, the study did not include a follow-up to analyze the maintenance of attentional changes over time.

The present study used a novel methodology to investigate attentional changes using emotional stimuli. Future studies should confirm the sensitivity of the procedure when using other types of stimuli (e.g., different types of emotions), samples of participants (e.g., novices vs experts) or types of meditation. Also, considering the methodological limitations of self-report measures to quantify subtle aspects of meditation (Baer, 2019; Vago et al., 2019), it would be interesting to explore if this novel emotional attentional blink task could be used as a valid indirect measure of, for example, equanimity (Desbordes et al., 2015). As future lines of studies, it could be important to assess the stability of the changes by using longitudinal studies and the relationships between those cognitive changes and behavioral changes, which are one of the ultimate goals of meditation programs.

Our findings provide evidence that meditation trainings could help to balance out the salience of negative stimuli in participants' cognitive systems by improving the processing of positive and neutral stimuli. Knowing more about how meditation practice affects attentional regulation toward emotional information would allow us to identify the action mechanisms that enhance adaptative mood regulation strategies and well-being related to these practices.

Compliance with Ethical Standards: Participants gave their informed consent prior to their inclusion in the study. Furthermore, the study was approved by the university ethics committee prior to participant recruitment and was registered at ClinicalTrial.org (NCT03920241).

Conflicts of interest: The authors declare that they have no conflict of interest.

Open Practices: All data are publicly available and can be accessed at https://github.com/nirakara-lab/AB-MEDITATORS.git. The study was approved by the university ethics committee prior to participant recruitment and was registered at ClinicalTrial.org (NCT03920241).

Author Contributions: PR and CV developed the study concept and study design. Testing and data collection were performed by PR. Data analysis and interpretation was performed by PR under the supervision of CV. PR and CV drafted the manuscript. Both authors approved the final version of the manuscript for submission.

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CHAPTER 8

PSYCHOLOGICAL EFFECTS AND MECHANISMS OF CHANGE IN MEDITATION

The Chapter 8 corresponds to the published article with the following reference:

Roca, P., Vazquez, C., Diez, G. G., Brito-Pons, G., & McNally, R. J. Not all types of meditation are the same: Mediators of change in mindfulness and compassion meditation interventions. *Journal of Affective Disorders* (under review).

Despite the wide range of research of meditation benefits on psychological distress and well-being (Chapter 1), we still do not know exactly *how* and *why* meditation works. As described in Chapter 2, several theoretical models have explored the potential mechanisms of change underlying the MBPs. However, more empirical studies are needed to understand the core mechanisms associated to psychobiological changes associated to MBPs. Moreover, the scope of scientific research has been focused almost exclusively in mindfulness meditation, and other forms of meditation have not received the scientific attention they deserve (Dahl & Davidson, 2019). Several studies suggest that mindfulness and compassion meditation may yield different psychological effects and involve different mechanisms of change (see Chapter 3). Clarifying these mechanisms would improve the efficacy of MBPs, as well as the inclusion of meditation practice in broader psychological treatment protocols and in the healthcare system (Brown et al., 2007; Craig et al., 2008). Therefore, the second study aimed to examine the relative effectiveness and mediators of change in mindfulness and compassion standardized programs.

Not all types of meditation are the same: Mediators of change in mindfulness and compassion meditation interventions

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Abstract

Background: The general aim of the study was to examine the relative effectiveness and mediators of change in standardized mindfulness and compassion interventions.

Methods: A sample of 431 participants enrolled in a Mindfulness-Based Stress Reduction program (MBSR = 277) and a Compassion Cultivation Training (CCT = 154). The assessment before and after the program included a set of outcomes and mediators measures. Four steps data analysis plan was followed: ANOVA, ANCOVA, Reliable Change Index and mediations (simple and multiple).

Results: Both interventions yielded increases in mindfulness, decentering, body awareness and self-compassion. Yet, present-moment awareness changes (i.e., trait mindfulness, decentering and body awareness) were significantly larger in the MBSR, whereas socio-emotional changes (i.e., common humanity and empathic concern) were larger in the CCT. The magnitude of effect sizes ranged from medium to large. Furthermore, both mindfulness and compassion interventions yielded similar changes in psychological distress (i.e., stress, anxiety and depression), psychopathology outcomes (i.e., rumination and thought suppression), and well-being. The mediation models showed that while the MBSR program seems to use changes in present-moment awareness mechanisms (i.e., decentering and body awareness) to reduce psychological distress and to improve well-being, the CCT program seems to lead to the same positive outcomes through changes in prosocial and emotional mechanisms (i.e., common-humanity and empathy concern).

Limitations: Due to our naturalistic design in real-world community setting, it was infeasible to randomly assign participants.

Conclusions: Our results suggest that “what you practice matters”, showing that both interventions achieved similar results through different pathways.

Key words: mindfulness, compassion, meditation types, mediators, action mechanisms.

INTRODUCTION

Research on meditation has grown exponentially (Kabat-Zinn, 2019), documenting the benefits of Mindfulness-Based Interventions (MBIs) for people with psychological disorders and medical conditions (Goldberg et al., 2018; Greeson and Chin, 2019) as well as for healthy individuals (Sedlmeier et al., 2018). Yet the mechanisms mediating benefits of different MBIs, such as Mindfulness Based Stress Reduction (MBSR) and Compassion-Based Interventions (CBIs) remain understudied (Dahl et al., 2015; Gu et al., 2015; Kirby et al., 2017).

Mindfulness signifies attending to one's immediate experience nonjudgmentally (Kabat-Zinn, 2003), whereas *compassion* denotes sensitivity to the suffering of oneself and others with a commitment to prevent it and relieve it (Gilbert and Choden, 2013). Although "mind training" is central to both mindfulness and compassion practices, differences are evident (Jinpa, 2019): 1) being in the present moment is the core of mindfulness, whereas compassion includes exercises evoking past and future scenarios; 2) whereas mindfulness mainly trains a nonjudgmental attitude, compassion practice trains the affective states of empathy, warmth, and kindness toward oneself and others; 3) contemporary mindfulness also promotes the observer's neutral standpoint, whereas compassion emphasizes the appraisal of one's thoughts and feelings; and 4) compassion training has a more prominent ethical component than does mindfulness training. Hence, mindfulness training emphasizes cognition and attention, whereas, compassion training emphasizes socio-affective aspects. Despite the difference in emphasis, affective and cognitive processes figure in both approaches (Dahl et al., 2016). As meta-analyses have shown, MBIs significantly reduce stress, anxiety, depression, and increase quality of life (Gotink et al., 2015; Khoury et al., 2015), and enhance psychological well-being (Carmody and Baer, 2008). Meta-analyses also suggests that CBIs significantly increase (self) compassion, mindfulness and well-being, while reducing anxiety, depression and psychological distress (Kirby et al., 2017).

Despite the growing scientific interest in mindfulness and other forms of meditation, few studies have investigated the differential effects of various practices (Dahl and Davidson, 2019). In a pioneering study, Brito-Pons and colleagues (Brito-Pons et al., 2018) compared the effects of compassion and mindfulness standardized programs, finding that both programs were similarly effective in enhancing well-being, mindfulness, and compassion skills. Yet, the compassion program had a greater impact on compassion-related measures (i.e., self-compassion, empathic concern, and common humanity). However, most comparative studies on meditation modalities have been conducted with relatively small sample sizes and confined to the comparison of average overall scores, a limited strategy that does not elucidate differential action mechanisms between interventions.

In this study, we examined the relative effectiveness and mediators of change in mindfulness and compassion standardized programs: Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 2013) and Compassion Cultivation Training (CCT; Goldin & Jazaieri, 2017). We tested whether (1) mindfulness and compassion meditation programs enhance mindfulness, compassion, and well-being, while reducing psychological distress (i.e., stress anxiety and depression) and psychopathology outcomes (i.e., rumination and thought suppression); and (2) whether changes in mindfulness and compassion associated with each program individually (i.e., simple mediations) and simultaneously (i.e., multiple mediations) mediate changes in psychological distress and well-being. Accordingly, we hypothesized that although both programs should improve levels of mindfulness and compassion, MBSR would be more effective than CCT in boosting mindfulness but less effective enhancing compassion. Second, we expected that despite an overall improvement in symptoms of distress, MBSR would be more effective than CCT in reducing stress-anxiety but less effective than CCT in diminishing depression, whereas both programs would similarly enhance well-being. Third, we predicted that the mechanisms mediating the relationship between the programs and their effects on psychological distress and well-being would differ between programs. More specifically, we expected that increases in mindfulness, decentering, and body awareness would mediate the relationship between MBSR and its main psychological outcomes, whereas increases in compassion and empathy would mediate the relation between CCT and its main psychological outcomes.

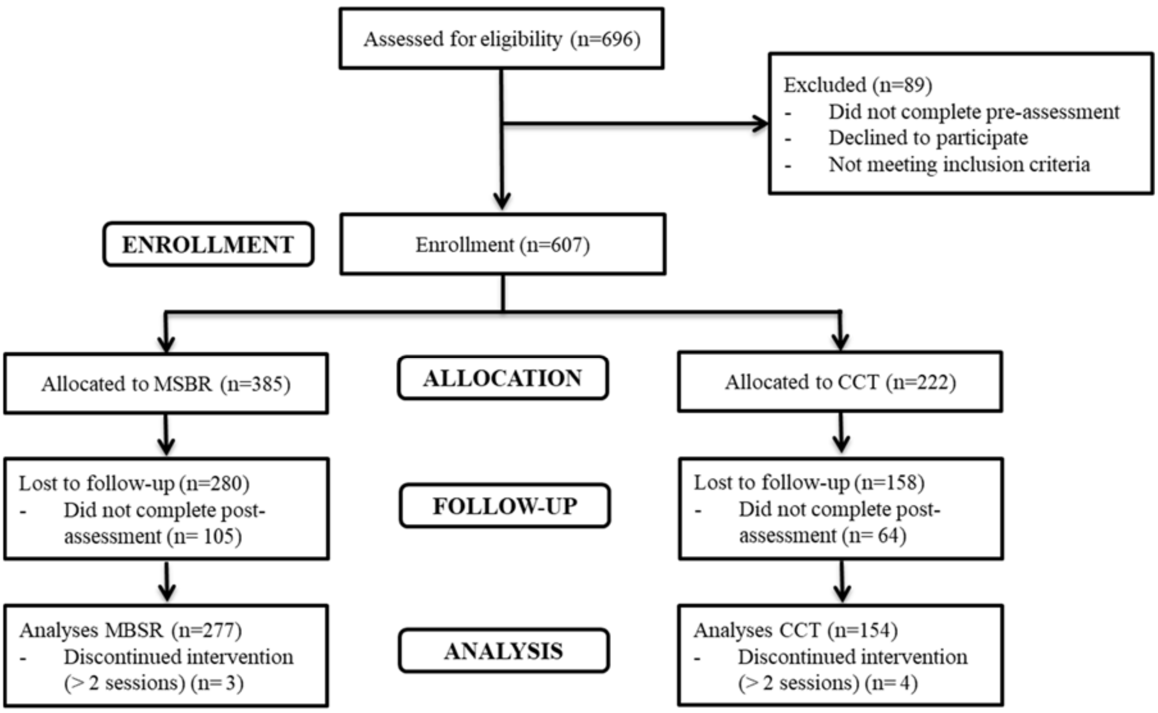
METHOD

Participants

We analyzed the data of 431 participants: 277 in MBSR and 154 in CCT (see Figure 1). Participants' mean age was 45.94 (*SD*= 10.17), 73.5% were women, 78.3% had university studies, 44.1% were married, and 7.6% were unemployed. The mindfulness and compassion groups did not differ in gender ($\chi^2_{(2)}$ = 2.73, p = .26), nationality ($\chi^2_{(7)}$ = 8.76, p = .27), and education ($\chi^2_{(7)}$ = 4.13, p = .77). However, the MBSR group was younger than the CCT group ($t_{(436)}$ = -3.66, p<.001; $MBSR_{age}$ = 44.62; CCT_{age} = 48.27) and reported practicing less weekly formal meditation before starting the program ($t_{(436)}$ = -5.22, p<.001; $MBSR_{practice}$ = 57.78 min; $CCT_{practice}$ = 130.71 min).

Inclusion criteria were as follow: 1) being 18 years old or above; 2) not having any current serious physical illness, psychological disorders or substance abuse; 3) having completed both pre- and post-assessments; and 4) having attended at least 6 of the 8 sessions (i.e., 75% of the program). G*Power (v. 3.1) was used to estimate sample size (see further details in Supplementary Materials).

Figure 1. Participants flow diagram.



Procedure

Participants were invited to join the study during the registration phase on the university's official website offering the MBSR and CCT programs. Participants then filled out a brief online screening questionnaire on demographics and inclusion criteria and gave their informed consent prior to their inclusion in the study. The procedure included the completion of an online assessment (via Qualtrics software) during the week before starting the program (i.e., pre-assessment) and during the week after its completion (post-assessment). At the end of the last assessment session participants were debriefed on the goals of the study and were given a complimentary individualized report on their changes in the questionnaires used in the program. The research was approved by the university ethics committee prior to participant recruitment (Ref 2016/17-016) and was registered at ClinicalTrial.org (NCT03920241).

Programs description (MBSR and CCT)

MBSR and CCT are 8-week evidence-based programs that offer a secular meditation training, combining insights and techniques from Western psychology and contemplative practice. The programs are conducted in groups of 20-30 participants, and consist of 2.5-hour of face-to-face sessions per week and 30-45 minutes of daily practices (formal and informal). The MBSR program is aimed at cultivating awareness by paying attention in the present moment to any stimulus that comes to one’s own mind with an acceptance and non-judgmental disposition. During the MBSR participants perform different mindfulness practices including focused attention on the breath, open monitoring of awareness in body-scanning and simple yoga postures. In contrast, Compassion Cultivation Training (CCT) is aimed at cultivating compassion and empathy toward oneself and others. During the CCT different compassion exercises are practiced, including loving kindness and compassion for a loved one, for oneself and toward others, as well as active compassion practices (known as *tonglen*), which involve explicit evocation of the altruistic wish to do something about others’ suffering. Furthermore, each participant was given, at the end of every session, a set of pre-recorded audio files and a workbook to support their daily practices. The MBSR program was guided by three certified instructors by the Mindfulness Center at Brown University (https://www.brown.edu/public-health/mindfulness/home) and the CCT program was applied by two certified instructors by the Center for Compassion and Altruism Research and Education at Stanford University (http://ccare.stanford.edu). Program fidelity is continuously supported through regular group supervision meetings.

Measures

Different outcomes measures and core mediators were included in the online assessment. The selection of measures was based on a literature review of the theoretical models of meditation action mechanisms (Gu et al., 2015; Hölzel et al., 2011; Kirby et al., 2017; Roca et al., 2019), as well as the modules and techniques included in both programs. Table 1 lists the outcome measures and mediators of change measures and the internal consistency scores (i.e., Cronbach's alpha) for this sample.

Table 1: Outcomes and mediators measures used in this study.

Outcome measures
Depression Anxiety Stress Scales (DASS-21, 21 items [α = .92]; Lovibond & Lovibond, 1995). A widely used measure assessing depression, anxiety and stress symptoms during the past week.
Pemberton Happiness Index (PHI, 11 items [α = .92]; Hervás & Vázquez, 2013). An integrative measure of psychological well-being. In this study only the remembered well-being total score was included.
Mediators of change measures
Five-Facet Mindfulness Questionnaire-Short Form (FFMQ, 20 items [α = .89]; Baer et al., 2006). A widely used measure of mindfulness including five factors (describing, acting with awareness, observing, non-judging of inner experience, and non-reactivity to inner experience) and a total score.
Experiences Questionnaire (EQ, 11 items [α = .90]; Fresco et al., 2007). A measure of the capacity to observe our feelings and thoughts without being attached to them (i.e., decentering).
Multidimensional assessment of interoceptive awareness (MAIA, 32 items [α = .95]; Mehling et al., 2012). A multidimensional measure of interoceptive body awareness that includes eight dimensions (noticing, not distracting, not worrying, attention regulation, emotional awareness, self-regulation, body listening and trusting) and a total score.
Self-Compassion Scale-Short Form (SCS-SF, 12 items [α = .91]; Raes et al., 2011). A measure of compassion to oneself that includes three main components: mindfulness, self-kindness and common humanity.

Interpersonal Reactivity Index (IRI, 7 items [α = .68]; Davis, 1980). A multidimensional measure of empathy towards others. In this study only the Empathic Concern scale was included, defined as the emotion of caring for others who are suffering.

Ruminative Response Style (RRS, 22 items [α = .92]; Nolen-Hoeksema & Morrow, 1991). Rumination is defined as the chronic tendency to focus on the causes and consequences of our distress without moving into active problem-solving. This measure includes two factors: cognitive reflection and brooding.

White Bear Suppression Inventory (WBSI, 10 items [α = .88]; Wegner & Zanakos, 1994). It measures, chronic thought suppression (i.e., a tendency to suppress unwanted intrusive thoughts).

Data analysis

The data analysis plan was conducted following four successive steps (see further details in Supplementary Materials). First, a 2 (program: MBSR vs CCT) x 2 (time: pre vs post) mixed ANOVA tested whether the MBSR and CCT produced significant changes in outcomes and mediators. Second, a mixed ANCOVA tested whether the outcomes and mediators changed after we controlled for previous experience with meditation and age of participants. Third, following Britton's (Britton, 2019) suggestions to improve individual-level analysis and the detection of potential adverse effects in meditation studies (Cebolla et al., 2017), we computed the Reliable Change Index (RCI; Jacobson & Truax, 1992). The RCI characterizes changes in outcomes (i.e., stress, anxiety, depression, and well-being) in terms of clinically meaningful gains and deteriorations. Finally, mediation analyses examined whether mindfulness and compassion changes after the program mediated the efficacy of the programs on psychological distress and well-being. Both simple mediation (i.e., one mediator) and multiple mediation (i.e., more than one mediator simultaneously) were conducted on change scores (i.e., post-pre scores), by using pre-intervention outcomes scores and pre-intervention mediators scores as covariates in the analysis to control for baseline differences between groups. Only those measures showing significant differences between MBSR and CCT programs in the ANOVA were introduced in the mediations. SPSS 25 was employed for all analyses, using PROCESS macro tool (version 3.4) to performed mediation analyses following Hayes (Hayes, 2018) technical recommendations. The data are available at https://github.com/nirakara-lab/MBSR-vs-CCT.git (DOI: 10.5281/zenodo.4056691).

Results

***Hypothesis 1 and 2*: Changes in outcomes and mediators after MBSR and CCT programs (Mixed ANOVA, ANCOVA, and RCI).**

The ANOVA assumptions were fulfilled for all measures (see Supplementary Materials). Regarding present-moment awareness measures, the only significant Program x Time interactions were for FFMQ Observing ($F_{(1, 429)}$ = 6.37, p =.012, η^2_p = .02; 1-β = .71), FFMQ mindfulness total score ($F_{(1, 429)}$ = 5.06, p =.025, η^2_p = .01; 1-β = .61), EQ decentering ($F_{(1, 429)}$ = 10.21, p =.002, η^2_p = .02; 1-β = .89), MAIA noticing ($F_{(1, 429)}$ = 10.98, p =.001, η^2_p = .03; 1-β = .91), MAIA not worrying ($F_{(1, 429)}$ = 11.09, p =.001, η^2_p = .03; 1-β = .91), MAIA attention regulation ($F_{(1, 429)}$ = 37.22, p < .001, η^2_p = .08; 1-β = 1.00), MAIA self-regulation ($F_{(1, 429)}$ = 22.17, p < .001, η^2_p = .05; 1-β = .99), MAIA body listening ($F_{(1, 429)}$ = 18.70, p < .001, η^2_p = .04; 1-β = .99), MAIA trusting ($F_{(1, 429)}$ = 15.10, p < .001, η^2_p = .03; 1-β = .97), and MAIA total scores ($F_{(1, 429)}$ = 35.35, p < .001, η^2_p = .08; 1-β = 1.00). Pairwise Bonferroni-corrected comparisons indicated that both groups significantly increased their levels of mindfulness, decentering, and body awareness. However, these gains were significantly larger in MBSR than in CCT (see Supplementary Table 1).

Regarding socio-emotional measures, the only significant Program x Time interaction was for SCS common humanity ($F_{(1, 429)}$ = 9.86, p =.00, η^2_p = .02; 1-β = .88), and IRI empathic concern ($F_{(1, 429)}$ = 7.85, p =.005, η^2_p = .02; 1-β = .80). Pairwise Bonferroni corrected comparisons indicated that both groups significantly increased their levels of common humanity level, that is, to recognize that suffering is part of the shared human experience, understanding that everyone fails and make mistakes. But only participants in the CCT increased their empathic concern (see Supplementary Table 1).

In regard to psychological distress and psychopathology outcomes (i.e., stress, anxiety, depression, rumination, and thought suppression), there was a significant Time main effect on all these measures, showing that improvements in psychological distress and psychopathological measures were similar in both programs (see Supplementary Table 1). Program x Time interaction was not significant for any of these measures: DASS stress ($F_{(1, 429)}$ = 2.14, p =.14), DASS depression ($F_{(1, 429)}$ = .14, p =.71), DASS anxiety ($F_{(1, 429)}$ = .10 p =.75), RRS brooding ($F_{(1, 429)}$ = 2.37, p =.12), RRS reflection ($F_{(1, 429)}$ = 2.21, p =.14), and WBSI thought suppression ($F_{(1, 429)}$ = 1.85, p =.17). Similarly, a significant Time main effect on the PHI showed an increase on psychological well-being that was similar in both programs as the Program x Time interaction was not significant ($F_{(1, 429)} = 1.78$, p =.18).

The results of the two-way mixed ANOVA also revealed a significant Time main effect for all outcomes and mediators assessed, indicating that there were significant changes in the expected direction after both meditation programs. Furthermore, Supplementary Table 1 shows that the pre-post changes after the MBSR and CCT programs had medium to large effect sizes.

Furthermore, two-way mixed ANCOVAs were conducted in order to examine whether the changes in outcomes and mediators after the MBSR and CCT programs remained the same after controlling the heterogeneity caused by the influence of previous meditation experience and the age of participants. Although some caution must be taking in interpreting this analytic approach (Miller and Chapman, 2001), the results of the ANCOVAs showed the same results as the mixed ANOVA and only FFMQ mindfulness total score interaction was marginally significant after controlling for the influence of previous practice ($F_{(1, 428)} = 2.83$, p =.063).

The RCI analyses indicated that no significant differences between MBSR and CCT in terms of clinically significant change in stress ($\chi^2_{(3)} = 3.42$, $p = .33$), depression ($\chi^2_{(3)} = 3.23$, $p = .36$), and well-being ($\chi^2_{(3)} = 4.52$, $p = .21$). Yet, for anxiety, the MBSR program had significantly fewer participants with no changes than did the CCT program [41.1% vs 53.2%; ($\chi^2_{(3)} = 8.76$, $p = .033$)] (see further details in Supplementary Materials and Supplementary Figure 1).

***Hypothesis 3.1*: mediators of change in MBSR and CCT (single mediation models).**

Only those measures showing significant differences between MBSR and CCT programs in the ANOVA were selected as potential mediators of changes in psychological distress and well-being. The meditation assumptions were fulfilled for all the measures (see Supplementary Materials). Supplementary Table 2 shows the unstandardized regression coefficients for changes in stress, anxiety, depression, and psychological well-being after MBSR and CCT. The percentage of variance (R^2) explained by the mediation models was quite high, exceeding 30% in all cases. More specifically, our analyses showed that:

a) The effects of MBSR and CCT programs on stress symptoms were entirely mediated by EQ Decentering, MAIA Noticing, MAIA Not-Worrying, MAIA Attention Regulation, MAIA Self-Regulation, MAIA Body Listening, MAIA Trusting, MAIA Total and SCS Common Humanity.

b) The effects of MBSR and CCT on anxiety symptoms were entirely mediated by EQ Decentering, MAIA Not-Worrying, MAIA Attention Regulation, MAIA Trusting, MAIA body awareness total score, and SCS Common Humanity.

c) The effects of MBSR and CCT programs on depression symptoms were totally mediated by EQ Decentering, MAIA Attention Regulation, MAIA Trusting, MAIA body awareness total score, and SCS Common Humanity.

d) Finally, the effects of MBSR and CCT programs on psychological well-being were totally mediated by EQ Decentering, MAIA Noticing, MAIA Not-Worrying, MAIA Attention Regulation, MAIA Body Listening, MAIA Trusting, MAIA body awareness total score, SCS Common Humanity, and IRI Empathic Concern.

Synthesizing these results, a number of general conclusions can be drawn. Firstly, regarding a-path, MBSR program significantly predicted greater increases in measures of decentering and body awareness, whereas CCT significantly predicted greater increases on measures of common-humanity and empathy. Second, regarding b-path, mediators were negatively related to psychological distress outcomes (i.e., stress, anxiety and depression) and positively related to psychological well-being. Hence, increases in mindfulness and compassion were significantly associated with lower stress, anxiety, and depression and increased well-being.

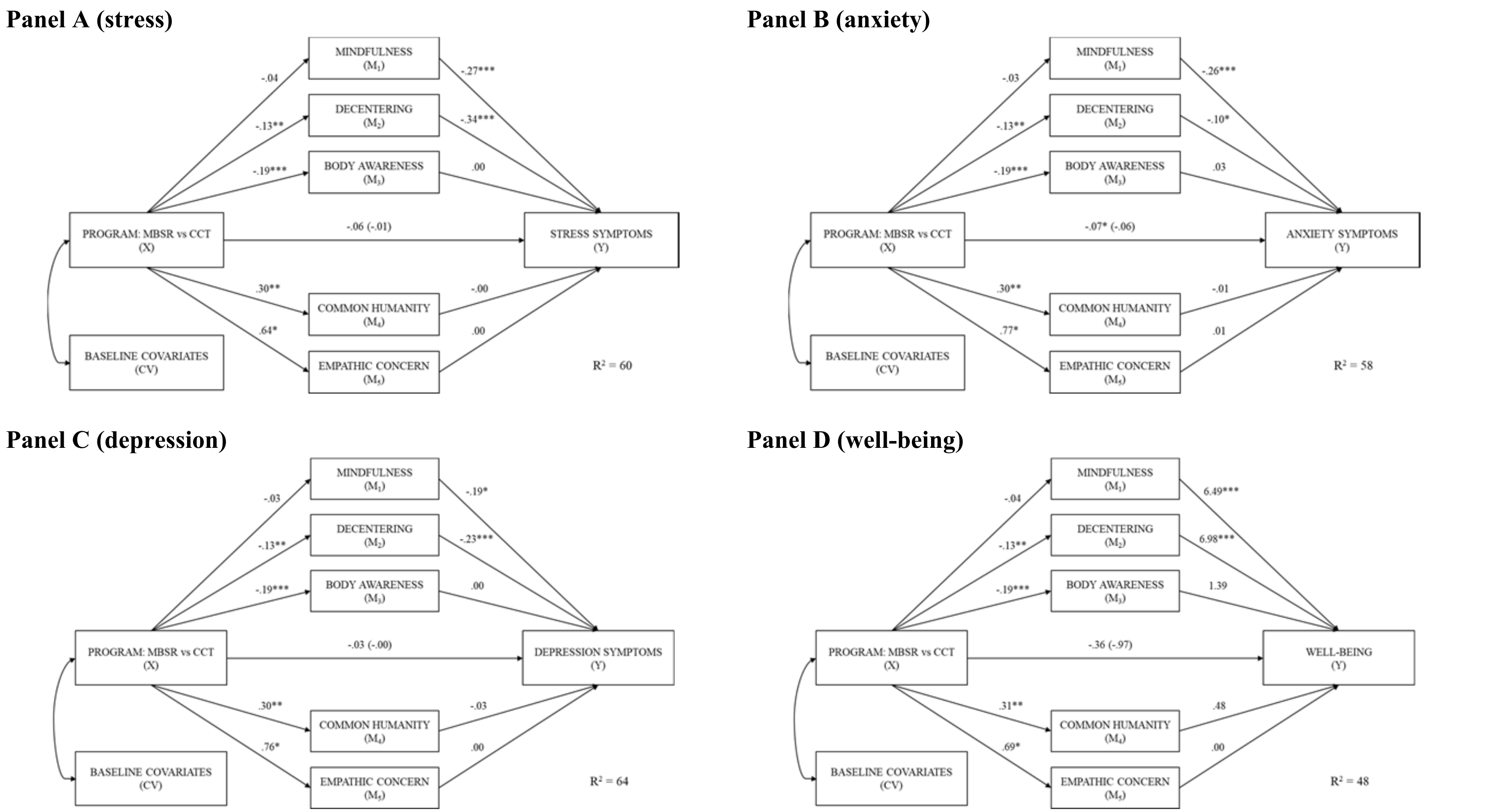
***Hypothesis 3.2*: mediators of change in MBSR and CCT (multiple mediation models).**

Finally, after data screening and testing assumption as before, we conducted mediational analyses including all mindfulness and compassion total scores as mediators in the model, controlling for baseline levels. Figure 2 shows the unstandardized regression coefficients for changes in stress, anxiety, depression, and well-being after MBSR and CCT.

For all four models, the a-paths were significant (except FFMQ mindfulness) and the b-paths were only significant for FFMQ mindfulness and EQ decentering. The direct and total effects (c'-path and c-path) were nonsignificant for stress, depression, and well-being. However, for anxiety the direct effect (c'-path) was significant. The total model explained considerable variance in symptom reduction – stress (64%), anxiety (58%), and depression (64%) – plus 48% of the improvement in well-being. Only the indirect effect of EQ decentering was significant in the four mediation models (stress: *ab* = 0.05; *s.e.* = 0.02; 95% CI [0.02, 0.08]; anxiety: *ab* = 0.01; *s.e.* = 0.01; 95% CI [-0.0003, 0.03]; depression: *ab* = 0.03; *s.e.* = 0.01; 95% CI [0.01, 0.05]; and well-being: *ab* = -0.91; *s.e.* = 0.35; 95% CI [-1.67, -0.29]), suggesting that the relationship between the programs, the reductions in stress and depression symptoms and the improvements in well-being were totally mediated by changes in decentering, and partially mediated in the case of anxiety.

The 95% CIs of the post-hoc pairwise contrasts between the indirect effects of the different mediators showed that EQ decentering was the strongest mediator in all models. Regarding stress, EQ decentering was stronger than FFMQ mindfulness (*ab* = -0.06; *s.e.* = 0.02; 95% CI [0.02, 0.08]), MAIA body awareness (*ab* = -0.05; *s.e.* = 0.02; 95% CI [0.01, 0.09]), SCS common humanity (*ab* = -0.05; *s.e.* = 0.02; 95% CI [0.01, 0.08]), and IRI empathic concern (*ab* = -0.04; *s.e.* = 0.02; 95% CI [0.01, 0.08]). Regarding anxiety, EQ decentering was stronger than SCS common humanity (*ab* = 0.02; *s.e.* = 0.01; 95% CI [0.0001, 0.03]). Regarding depression, EQ decentering was stronger than FFMQ mindfulness (*ab* = -0.02; *s.e.* = 0.01; 95% CI [-0.05, -0.002]), MAIA body awareness (*ab* = 0.03; *s.e.* = 0.02; 95% CI [0.009, 0.07]), SCS common humanity (*ab* = 0.04; *s.e.* = 0.01; 95% CI [0.01, 0.06]), and IRI empathic concern (*ab* = 0.03; *s.e.* = 0.01; 95% CI [0.01, 0.05]). Finally, regarding well-being, EQ decentering was stronger than SCS common humanity (*ab* = -1.04; *s.e.* = 0.37; 95% CI [-1.81, -0.36]), and IRI empathic concern (*ab* = -0.91; *s.e.* = 0.35; 95% CI [-1.67, -0.28]).

Figure 2. Multiple mediation model of stress (Panel A), anxiety (Panel B), depression (Panel C) and well-being (Panel D) changes after the MBSR and CCT programs. The c-path is provided in brackets. *Note*: * $p < .05$; ** $p < .01$; and *** $p < .001$.



DISCUSSION

The general aim of the study was to examine the relative effectiveness and mediators of change in standardized mindfulness and compassion interventions. Specifically, we assessed whether mindfulness (MBSR) and compassion (CCT) programs enhanced mindfulness, compassion, and well-being scores while reducing psychological distress (i.e., stress, anxiety and depression) and rumination. Moreover, we explored whether changes in levels of mindfulness and compassion mediate changes in psychological distress and well-being.

Based on previous studies (Brito-Pons et al., 2018; Singer and Engert, 2019), we hypothesized that both programs would improve levels of mindfulness and compassion, but that MBSR would be more effective than CCT at improving mindfulness but less effective in enhancing compassion. Analyses of variance showed that both programs increased mindfulness, decentering, body awareness, and self-compassion scores. Yet, present-moment awareness improvements (i.e., trait mindfulness, decentering and body awareness) were significantly larger in the MBSR program, whereas socio-emotional changes (i.e., common humanity and empathic concern) were larger in the CCT program. Furthermore, the magnitude of effect sizes ranged from medium to large.

Hence, some beneficial effects occur following both programs, whereas certain ones seem specific to MBSR and CCT, respectively, as others have found (Brito-Pons et al., 2018; Hildebrandt et al., 2017). Both MBSR and CCT improved core 'cognitive' and 'emotional' aspects of functioning. Neither program is wholly "cognitive" nor wholly "affective" (Grossman, 2019). Indeed, mindfulness plays a foundational role for other meditation practices (Dahl and Davidson, 2019) and attending to one's experience is common to all of them. In contemporary MBSR, compassion is taught implicitly as an attitudinal foundation of mindfulness and is modeled by the instructors' behaviors and attitudes (Neff and Dahm, 2015). In the same manner, mindfulness is formally practiced during the first week of CCT program as a foundation for subsequent compassion meditations (Jinpa, 2010), and compassion exercises demand different cognitive operations such as being able to pay close attention to different aspects of the internal and external experience and to reappraise suffering and hardship (Dahl et al., 2016).

Considering the similarities and differences between mindfulness and compassion practices (Jinpa, 2019), as well as the changes in clinical outcomes found in both programs (Khoury et al., 2015; Kirby et al., 2017), we hypothesized that despite an overall improvement in symptoms of distress, MBSR would be more effective than CCT in reducing stress and anxiety symptoms but less effective in diminishing depression, whereas both programs would enhance well-being. The results did not support this hypothesis. Both mindfulness and compassion interventions similarly reduced psychological distress (i.e., stress, anxiety and depression) and psychopathology outcomes (i.e., rumination and thought suppression) while increasing well-being. Also, RCI analyses indicated that the groups did not differ on this index (except for anxiety). The variable showing the largest proportion of beneficial change was well-being (i.e., 75.4%), perhaps because our participants were not clinical patients. Finally, only a tiny fraction of participants exhibited any deterioration from baseline, which is an important result considering the potential adverse effects of meditation practice in some individuals (Cebolla et al., 2017). Our results are broadly consistent with previous work (Brito-Pons et al., 2018; Khoury et al., 2015; Kirby et al., 2017).

Finally, our third hypothesis concerned whether the core mechanisms mediating the relation between the mindfulness and compassion programs and the outcomes (i.e., psychological distress and well-being) would differ in each program. Specifically, we expected that changes in mindfulness, decentering, and body awareness would mediate the relationship between MBSR and the main psychological outcomes, while changes in compassion and empathy would mediate the relationship between CCT and those same outcomes. The results suggested that psychological distress and well-being were entirely mediated by mindfulness and compassion-related measures after controlling for baseline differences. The effects of mindfulness and compassion interventions on stress, anxiety, depression, and well-being were entirely mediated by decentering, several body awareness scores, common humanity (self-compassion), and empathic concern (only in the case of well-being). The mediation models showed that the MBSR program significantly predicted higher decentering and body awareness increases after the program, while the CCT program significantly predicted higher common-humanity and empathy concern increases. All mindfulness and compassion mediators significantly predicted psychological distress reductions and well-being improvements after the program.

Considering both the second and the third hypotheses, the results suggest that different mediators of change are operating towards improvements in the same psychological outcomes. In other words, it seems that each program operates through different pathways to reduce psychological distress and to promote well-being. While the MBSR program seemingly relies on changes in present-moment awareness mechanisms (i.e., decentering and body awareness), CCT program seems to foster the same positive outcomes through changes in prosocial and emotional mechanisms (i.e., common-humanity and empathy concern). The similarities in psychological outcomes after mindfulness and compassion interventions may obscure important differences in mechanisms and this type of comparisons is essential for the next wave of research in the field (Crane et al., 2017). As other authors have pointed out (Rosenkranz et al., 2019), for example, both mindfulness training and aerobic exercise have shown to improve mood and sleep quality, although the mechanisms through which they produce these changes are quite different (i.e., regulation of autonomic arousal, decreased worry and rumination, and increased acceptance in the case of mindfulness, and thermoregulatory processes, cytokine release, and changes in circadian rhythms in the case of aerobic exercise). Another explanation for these results would be that overall scores on self-report measures are too coarse-grained or insufficiently reliable to identify subtle differences in interventions in general (Fried, 2015) and in meditation in particular (Grossman, 2019). Thus, future research should use behavioral and biological measures to programmatically analyze differences between meditation types (Desbordes et al., 2012; Roca and Vazquez, 2020), employing more sophisticated analysis (such as network analysis) to explore these differences (Roca et al., 2019).

Multiple mediational models, introducing simultaneously all the mindfulness and compassion mediators, showed that decentering was the strongest predictor and the only mediator with significant indirect effects on the four outcomes analyzed (i.e., stress, anxiety, depression, and well-being), after controlling by baseline differences. This result suggests that the relationship between mindfulness and compassion interventions and the changes in those outcomes after the program were totally mediated by changes in decentering. Furthermore, the multiple mediation model explained around 50-60% of the variance in psychological distress and well-being changes after the programs.

Decentering is defined as the meta-cognitive ability to observe stimuli arising in awareness (i.e., thoughts, emotions and sensations), with psychological distance and perspective taking (Fresco et al., 2007). Decentering may be one of the main mediators of change across a variety of meditation-based interventions (Bernstein et al., 2015; Dahl et al., 2015; Vago and Silbersweig, 2012; Wallace and Shapiro, 2006), being an essential component of mindful-emotion regulation processes (Crane et al., 2017; Hölzel et al., 2011). Moreover, improvements in decentering have been associated with enduring treatment changes for major depression and anxiety disorders (Farb et al., 2018; Hayes-Skelton and Lee, 2018), mediating also the wellbeing increases associated with mindfulness practice (van der Velden et al., 2015). It is likely that designing or refining meditation interventions with a focus on decentering may enhance their effects (Bernstein et al., 2019).

Our study has strengths and limitations. One of the main strengths is that by using a relatively large sample of participants and comparting active treatments, rather than a wait list, the study is aligned with some of the recent recommendations to improve the methodology of MBI studies (Dahl and Davidson, 2019; Van Dam et al., 2018). Two well-controlled standardized meditation interventions (i.e., highly structured formats and time-limited), taught by certified instructors, also improves the methodological control of external variables that could be affecting the results. Furthermore, a broad set of outcomes and mediators measures were selected according to the literature review on the theoretical models of meditation action mechanisms (Gu et al., 2015; Hölzel et al., 2011; Kirby et al., 2017; Roca et al., 2019). Finally, we used a rigorous mediation analysis based on the latest developments in the field (Hayes, 2018), and we used several covariates to control for baseline differences and third variables.

Our study has limitations. First, it was infeasible to randomly assign participants to MBSR and CCT. Indeed, participants self-selected into these programs. Accordingly, we cannot isolate MBSR and CCT as the cause of the beneficial changes occurring in the respective programs. Second, in contrast to patients in placebo-controlled drug trials, participants were not “blind” to their condition of the study. Although Randomized Controlled Trials (RCTs) remain the gold standard for causal inference, even RCTs can have limitations. For example, in one study comparing the relative efficacy of imipramine, pill placebo, and cognitive behavioral therapy for panic disorder, nearly half of the patients qualifying for the trial refused to be randomized either because they feared receiving medication or they were unwilling or unable to discontinue their current medication (Hofmann et al., 1998). This finding implies that the patients who participated in this RCT were biased in favor of CBT or least neutral regarding their views of the relative efficacy of medication versus psychosocial treatment. The upshot is that RCTs can have self-selection biases operating *prior* to randomization whereby a segment of the relevant population removes itself from consideration. Yet self-selection into a program can overestimate its potency relative to how it performs in an RCT (Lyubomirsky et al., 2011). Nevertheless, non-randomized comparisons still have probative merit. Although studies such as ours fall short of testing the relative *efficacy* of MBSR and CCT, they can provide an estimate of their relative *effectiveness* of these forms of meditation in the "real world."

However, some experts have suggested the need for moving from tightly controlled randomized control trials to practice trials in real-world community settings (Dimidjian and Segal, 2015; Greeson and Chin, 2019), in order to determine barriers and benefits outside of the idealized academic settings. Furthermore, in most cases the control groups do not match the contextual elements of the meditation interventions (e.g., motivation and expectation effects, group effects, teacher competency, or differences between experts and novices, among others). For this reason, non-inferiority trials could be a feasible alternative to compare the effects of meditation interventions (Hoge et al., 2019). Another limitation was that some participants had previous meditation experience from different traditions, although the degree of practice was statistically controlled in the analyses performed. Finally, the study did not include a follow-up to analyze the maintenance of the changes over time and the intersession changes during the intervention, which are necessary to test causal and temporal pathways.

Author Contributions: PR and CV developed the study conception and design. Testing and data collection were performed by PR and GD. Data analysis and interpretation was performed by GD and PR. The first draft of the manuscript was written by PR, under the close supervision of CV and RM. PR, CV, and RM drafted the manuscript. All the authors approved the final version of the manuscript for submission.

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CHAPTER 9 & 10

MINDFULNESS AND COMPASSION PROGRAMS FROM A NETWORK PERSPECTIVE

Chapters 9 & 10 correspond to the following published articles:

Roca, P., Diez, G. G., Castellanos, N., & Vazquez, C. (2019). Does mindfulness change the mind? A novel psychonectome perspective based on Network Analysis. *PloS one*, *14*(7). https://doi.org/10.1371/journal.pone.0219793

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There is a long tradition in clinical science of studying the processes and mechanisms of change underlying psychological interventions (Kazdin, 2007). Despite general consensus on the need to increase research on the mechanisms of change, the use of standard statistical approaches to analyze those mechanisms is more controversial (Hofmann et al., 2020). On one hand, mediation analysis (used in the second article of this dissertation, Chapter 8) has been the dominant approach to analyze mechanisms of change in psychological interventions for decades (Hayes, 2009). The traditional mediation approach assumes that changes resulting from the intervention are linear, unidirectional and contain few variables. However, treatment changes may involve a complex matrix of bi-directional relationships between multiple variables that change in non-linear and dynamic ways in response to the intervention. In recognition of this, the relationship between the outcomes and mechanisms may be best studied using network analysis (see Chapter 5 for more information on network analysis).

In the last decade, network analysis has been used as an innovative framework to understand psychopathology (Borsboom & Cramer, 2013; McNally, 2016). The network approach transfers the focus from changes within individual variables to the relations between them, which can shed light on structural psychological changes after an intervention. In fact, in the last years, network analysis has been increasingly used to analyze intervention-induced changes in symptoms, as well as shifts in association structures over time (Blanken et al., 2019). Therefore, we employed a network approach to explore the effects of mindfulness (Chapter 9) and compassion (Chapter 10) programs in terms of changes in the structure of relationships between psychological outcomes and mechanisms.

Does mindfulness change the mind?
A novel *psychonectome* perspective based on Network Analysis

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Abstract

If brain is a complex network of functionally specialized areas, it might be expected that mental representations could also behave in a similar way. We propose the concept of 'psychonectome' to formalize the idea of psychological constructs forming a dynamic network of mutually dependent elements. As a proof-of-concept of the psychonectome, networks analysis (NA) was used to explore structural changes in the network of constructs resulting from a psychological intervention. NA was applied to explore the effects of an 8-week Mindfulness-Based Stress Reduction (MBSR) program in healthy participants (N=182). Psychological functioning was measured by questionnaires assessing five key domains related to MBSR: mindfulness, compassion, psychological well-being, psychological distress and emotional-cognitive control. A total of 25 variables, covering the five constructs, were considered as nodes in the NA. Participants significantly improved in most of the psychological questionnaires. More interesting from a network perspective, there were also significant changes in the topological relationships among the elements. Expected influence and strength centrality indexes revealed that mindfulness and well-being measures were the most central nodes in the networks. The nodes with highest topological change after the MBSR were attentional control, compassion measures, depression and thought suppression. Also, cognitive appraisal, an adaptive emotion regulation strategy, was associated to rumination before the MBSR program but became related to mindfulness and well-being measures after the program. Community analysis revealed a strong topological association between mindfulness, compassion, and emotional regulation, which supports the key role of compassion in mindfulness training. These results highlight the importance of exploring psychological changes from a network perspective and support the conceptual advantage of considering the interconnectedness of psychological constructs in terms of a 'psychonectome' as it may reveal ways of functioning that cannot be analyzed through conventional analytic methods.

Keywords: Networks Analysis; Network Theory; Mindfulness-Based Stress Reduction; MBSR; Well-being; Psychopathology.

Introduction

Network theory and psychological functioning

Network theory (NT) has been used to describe the structure and functioning of dynamic complex systems by using Graph Theory [1,2]. The basic idea of NT is that systems can be represented as patterns of non-overlapping elements (represented as nodes) which are interconnected (represented as edges). The graph summarizes the pattern of relations among the elements in a network's topology [3].

Current conceptualizations of brain functioning use NT to describe the complex functioning of neural circuitries and their connection to different type of data (e.g. performance in cognitive tasks) which has opened the field of 'network neuroscience' [4]. Within this framework, it is nowadays widely assumed that brain operates as a network and such organization underlies information processing, emotions, sensations, or thoughts [5–7]. However, in standard current network approaches, such mental representations are still considered as independent entities for which, at least for some aspects of them (e.g. fear reaction, reward and episodic memory), neuroscience research has found underlying networks of neural activity [8,9]. Thus, unfortunately, psychological constructs are still far from being perceived as a psychological network itself. For instance, whereas attentional tasks are linked to ventral- and dorsal-attention networks [10], the connection between attention, and other cognitive components (e.g. working memory), or emotional components (e.g. anxiety) is almost entirely unknown [10,11].

NT and network analyses have also been recently used as an innovative framework to understand psychopathology [12]. The literature of NT in psychopathology has grown very rapidly in the last few years and has being applied to explore a relatively large variety of psychological problems as shown in a recent systematic review [13]. From a network perspective, psychological disorders are not entities leading to symptoms (as it has been commonly assumed in traditional causal models of mental disorders). Rather, psychological disorders are understood as networks of elements (basically, symptoms and signs) which are pairwise associated forming a dynamically complex system with potential mutual casual influences. Psychological disorders, according to this point of view, could be nothing else that the very network of interconnected symptoms [14,15]. The radical departure of network theory from other current diagnostic approaches is that it defines mental disorders as conditions consisting of strongly connected symptom networks, with no assumption of a latent entity subsumed under the symptoms [14]. Nevertheless, some network theorists have recently suggested that dwelling excessively on the lack of interest of latent variables may misguide the focus from what is more promising in conceptualizing disorders from a NA perspective (i.e., the idea of causally interconnected elements) [16,17]. In this sense, the use of psychological constructs (e.g., traits assessed by questionnaires), and not only elements like symptoms or signs, is beginning to be used in NA (e.g., [18–20]) and it could also be possible that, in the future, hybrid models, using not only elements like signs and symptoms but also latent variables, could shed light on the connections between psychological elements [21,22].

NT provides several advantages over previous models of psychopathology. Firstly, network analyses allow to empirically identify which nodes have a central role within the network, which departs from the Diagnostic and Statistical Manual's unproved assumption that all symptoms have the same diagnostic weight [23]. Secondly, and even more important, when longitudinal data are gathered, network analyses allow to explore potential causal links between the elements of the network [12,24], thereby identifying etiological pathways between symptoms (e.g. a sleep problem may lead to fatigue which leads to lack of energy and, finally, to anhedonia). Thirdly, network analyses also allow to explore time-related changes in the configuration of a given network which underlines the dynamic nature of psychological problems. These changes, that can be analyzed with mathematical tools [25], might be due to the mere passage of time or, more importantly, being the product of an intervention like the automatization of a cognitive task [26] or a psychological intervention [27,28]. Thus, analysis of different layers of networks along a temporal dimension (which may vary from milliseconds to months or years, depending on the type of study) allows to explore dynamic reorganizations of the elements of a network [25] which, in turn, may allow to identify key elements that can be targeted to promote changes in the network [29].

In sum, NT provides unique conceptual and analytic tools to understand in richer ways than in current prevailing models, the nature and etiology of mental disorders [15,30]. Expanding this approach to psychological models, in general, NT could provide a useful innovative paradigm to understand normal psychological functioning and its structure in a true holistic view [31].

The proposal of a '*psychonectome*'

Most of the psychology, psychiatry, and clinical and cognitive neuroscience experimental studies are based on gathering information from questionnaires or tasks to measure skills, knowledge, abilities, attitudes or personality traits with the aim to identify cognitive or clinical deficits and to find all type of behavioral, neurobiological, or contextual correlates. The way in which typically operates this approach of doing science is by assuming that scores from these tests somehow quantify the status of a particular psychological construct [32–34]. For example, it is assumed that a test measuring memory skills taps a construct relatively independent than another test measuring attention. Yet, despite this implicit assumption, the nature of mental functions and mental representations is more likely to be one of interconnectedness where each component operates in relation to others having complex dynamics of mutual relations. These mental functions and representations do not exist as absolute constructs that operate as independent modules. As it has happened in the history of neuroscience in relation to the understanding of the nature of neural activity (for a review see [35]), localizationism should be abandoned in psychology in favor of considering mind as a complex network of psychological constructs.

The network perspective has been fruitfully used in fields as diverse as the understanding of brain structures and functioning, mental disorders, microbiota or social interactions, to name a few [36–38]. Yet, NT could also be expanded to grasp a more complex view on the mutual dependencies of elements of psychological functioning. In the psychological realm, expanding the recent attempts to understand psychological disorders using NT, it could be hypothesized that psychological functioning might be modeled as a complex network of psychological variables or modules that may [39], or may not [40], be interconnected. Furthermore, using appropriate designs and analyses, that network might reveal that some elements causally influence others.

A network of psychological elements, following what Guloksuz et al. [41] have called the wave of the '-omics' approach (e.g. connectomics, genomics, or even 'symptomics' [42]), could be labelled as psychonectome. In general, a functional 'connectome' is the name given to those networks that reflect the activity of neural elements along a temporal dimension connecting neurons or regions (Friston, 2011; Korzeniewska et al., 2011). This psychonectome could be defined as a complex ensemble of dependences between psychological constructs (e.g. visuospatial memory, selective attention, or emotion regulation skills). That network might be, in turn, connected to more basic layers of elements belonging to the individual level (e.g. neural activity networks, signs and symptoms) or even elements external to the individuals (e.g. stressors, environmental circumstances) but still with the ability of activating some elements of other layers.

One of the most relevant features of the proposed *psychonectome* is that, as it happens in any network approach, the focus of interest is transferred from the individual variables or constructs (e.g. a behavioral response, socio-demographic information, or the score obtained from a psychological or clinical test) to the relation between them. The strength of a network is based on its decentralization and the synergy between its components is stronger than the sum of them. This new conceptualization of how systems work is being used not only to understand the functioning of complex systems but could also be fruitfully applied to understand the dynamic interconnections between psychological constructs as conceptualized in the *psychonectome* proposal.

A *psychonectome* approach to a mindfulness-based intervention

A good case where the idea of psychonectome could be applied is the field of mindfulness-based interventions (MBI) as they tap a variety of psychological constructs. Mindfulness (MF) is defined as a state of consciousness with a present-orientated attention, on purpose, and non-judging [43]. Although mindfulness meditation has its origin over 2500 years ago in the ancient Buddhist traditions [44,45], the incorporation of several secular practices of MF in the western world is quite recent [46] and has generated great interest in the scientific community and the general public alike [47].

Despite the wide range of research on meditation benefits to date [48], relatively few studies have attempted to examine the action mechanisms through which meditation produces its effects (for reviews see [49–54]. Most of the theoretical models published to date emphasize the central role of attention regulation, which is thought to underpin emotional and cognitive flexibility [52], which in turn improves the emotion regulation processes [55], and the ability to maintain non-judging awareness of thoughts, feelings and experiences. Theoretical models also emphasize the importance of body consciousness and changes in self–perspective [51,56], as well as the role of self-compassion [50] in the promotion of changes due to MBI practices.

The most widely evaluated MBI is the pioneer Mindfulness-Based Stress Reduction (MBSR; [43,57]). MBSR is a treatment program originally developed within a hospital context for the management of stress caused by chronic pain, and subsequently applied in an extensive variety of problems like the reduction of comorbid symptoms in other health problems such as fibromyalgia [58], mood changes in patients with cancer [59] or multiple sclerosis [60].

Several meta-analysis and a growing body of robust empirical evidence from randomized controlled trials show that MBI is a promising treatment for a variety of mental health problems, including anxiety disorder [61], stress [62], depression symptoms [63] and depression relapses [64], substance abuse [65], and eating disorders [66], among others.

In addition to reducing psychological symptoms, mindfulness practice has been also shown to have positive effects on psychological well-being in healthy participants [67], quality of life improvements [62], empathy, compassion and prosocial behaviors [68] and cognitive functioning [49,51].

The present study

Given the complex nature of mindfulness interventions and the well-studied cognitive, emotional, and psychopathological components that have been delineated in current theoretical models of mindfulness [51,52,69], it was considered that psychological changes associated to the practice of mindfulness would be an excellent proof of concept of the psychonectome idea.

As far as we know, NA has not been applied yet to explore the relationships among different psychological variables before and after a standardized MBSR intervention. Thus, the aim of this study was to examine the MBSR's impact on the network dynamics between mindfulness, compassion, well-being, psychological distress and emotional and cognitive control constructs, and how these constructs are reorganized after the intervention. Although this is likely the first study on network analysis applied to the field of mindfulness, we tested several inter-related hypotheses based on the extant evidence on the effects and mechanisms of MBSR. All the hypotheses are framed under two theoretical assumptions: The first one is that network analysis may reveal complementary information about the relation between psychological measures that cannot be inferred by standard univariate statistics (i.e. comparing pre and post scores on selected measures).

The second assumption is network analysis is able to find the dependences between constructs rather than the study of the constructs per se.

In sum, the following hypotheses were set up: 1) as supported by the literature review [48,50,61,62], the MBSR would yield significant changes, in an adaptive direction, in mindfulness, compassion, psychological distress, psychological well-being, and emotional and cognitive control variables; 2) after the MBSR program the networks of these constructs would become topologically reorganized (as measured by network paths and topological parameters) expecting a higher connectivity, clustering and efficiency; 3) based on theoretical models of MBSR functioning [52] it was also hypothesized that mindfulness, emotion regulation and well-being constructs would increase their centrality in the resulting psychonectome after the MBSR; and, 4) it was expected that these constructs would regroup after the MBSR in psychologically meaningful sub-networks as calculated by means of community analysis.

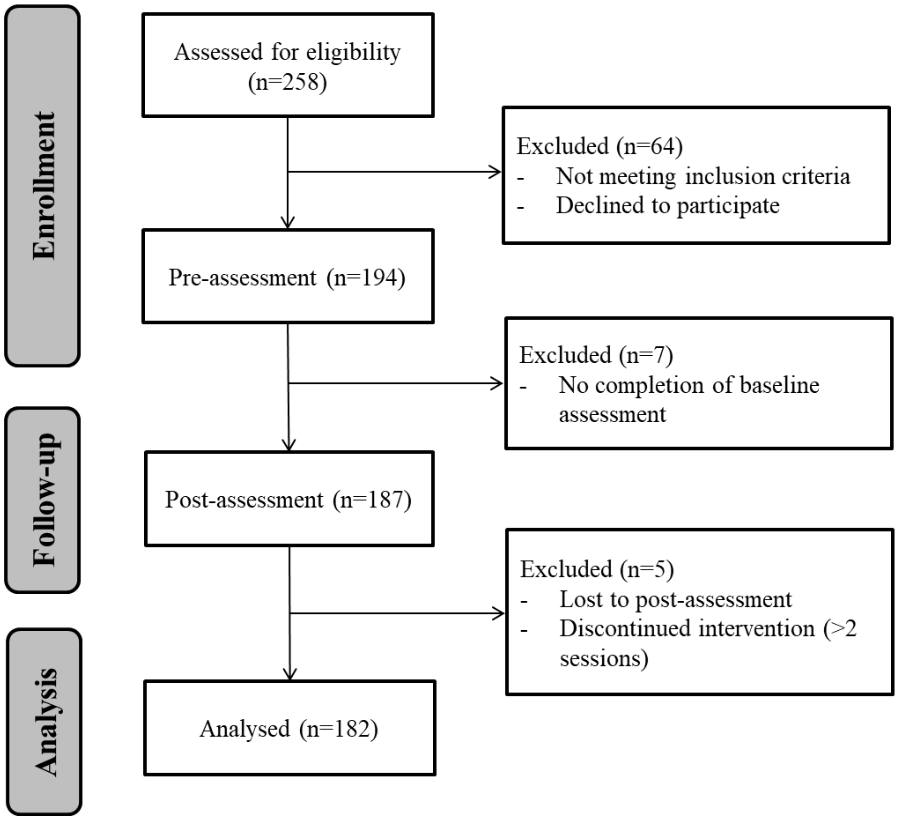
Methods

Participants

A sample of 258 adults, enrolled in a standardized 8-week MBSR program between April and December 2017, were invited to participate in this research (75.2% accepted to participate and fulfilled the inclusion criteria described below). After applying all exclusion criteria see Fig 1), data from a total of 182 individuals were included in all analyses. Participants mean age was 43.7 (*S.D.* = 9.77), 70.9% women, 95.7% had higher education, 40.1% married, 72.5% employed, 13,7% physical illness, 56% previous meditation experience and the meditation years average was 4.19 (*S.D.* = 5.72). The research study was approved by the university ethics committee prior to participant recruitment.

Inclusion criteria for MBSR program were as follows: 1) 18 years of age or more; 2) not having any current of serious psychological disorder or substance abuse / dependence. Statistical analyses were conducted only for data from participants who completed pre-assessment and attended a minimum of 6 sessions (i.e. 75% of the program). A precise description of the participation flow diagram is presented in Fig 1.

Figure 1. Participation flow diagram.



Procedure and materials

The study followed a pre-post design where the participants were blind to the aims of the study. Participants were invited to participate at the moment they registered in the official website offering the MBSR course. Those who accepted to participate, were administered a brief online screening questionnaire on demographics and inclusion criteria and were asked to sign an informed consent. Then participants were asked to complete online (via Qualtrics software) the set of questionnaires described in detail in the next section. The online assessment was completed the week before starting of the program (baseline assessment) and during the week after the end of the MBSR (post-assessment). When necessary, reminders were scheduled for those participants who hadn't completed the questionnaires. Each pre-post online evaluation lasted approximately 45 minutes. After completing the post-treatment assessments, participants were rewarded with an individualized report of their questionnaires scores.

Measures / Assessment

Sociodemographic and health information. For the baseline assessment a custom-made brief questionnaire, which included information about age, gender, education, occupation, psychological and physical health problems, was administered.

Meditation experience. A 32-item questionnaire, gathering information about previous meditation practice, meditation types and meditation retreats, was specifically designed for this study.

Constructs associated to mindfulness training. Five different areas, associated to the main outcomes and variables studied in the MF literature [52,70] were included. The constructs included:

a) *Mindfulness* (i.e. facets and mindfulness, decentering, non-attachment, and bodily awareness);

b) *Compassion* (i.e. compassion towards oneself and others and empathy)

c) *Psychological well-being* (i.e. satisfaction with life, optimism, and overall well-being).

d) *Psychological distress* (i.e. anxiety, stress, and depression)

e) *Emotional and cognitive control* (i.e. emotional regulation, rumination, thought suppression and attentional control)

Table 1 shows a brief description of the measures and the internal consistency scores found in our study (Cronbach’s alpha based on the polychoric correlations).

Table 1: Constructs and instruments used in the study

Mindfulness

- *Five-Facet Mindfulness Questionnaire-Short Form* (FFMQ, 20 items [α = .87]; [71]). It includes five component skills of mindfulness: observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience
- *Non-Attachment Scale* (NAS, 30 items [α = .93]; [72]). It measures the absence of fixation on thoughts, images, or sensory inputs, as well as an absence of internal pressure to get, hold, avoid, or change circumstances or experiences.
- *Experiences Questionnaire* (EQ, 11 items [α = .89]; [73]). It assesses the ability to observe one's thoughts and feelings in a detached manner.
- *Multidimensional assessment of interoceptive awareness* (MAIA, 32 items [α = .94]; [74]). It measures interoceptive body awareness.

Compassion

- *Self-Compassion Scale-Short Form* (SCS-SF, 12 items [α = .88]; [75]). It measures three components of compassion to oneself: self-kindness, common humanity, and mindfulness.
- *Compassion Scale* (CSP, 24 items [α = .86]; [76]). It assesses compassion to others, through the following components: kindness, indifference, common humanity, separation, mindfulness and disengagement.
- *Interpersonal Reactivity Index* (IRI, 14 items [α = .77]; [77]). It measures empathy towards others. In this study only the Empathic Concern subscale was included.

Psychological well-being

- *Satisfaction With Life Scale* (SWLS, 5 items [α = .87]; [78]). This is a measure of global life satisfaction.
- *Life Orientation Test–Revised* (LOT-R, 10 items [α = .67]; [79]). It measures dispositional optimism.
- *Pemberton Happiness Index* (PHI, 11 items [α = .91]; [80]). A measure that includes both hedonic and eudaimonic components of psychological well-being

Psychological Distress

- *Depression Anxiety Stress Scales* (DASS-21, 21 items [α = .92]; [81]). It measures symptoms of depression, anxiety and stress.

Emotional and cognitive control

- *White Bear Suppression Inventory* (WBSI, 10 items [α = .89]; [82]). It measures unwanted intrusive thoughts and thought suppression.
- *Ruminative Response Style* (RRS, 22 items [α = .92]; [83]). It assesses an excessive focus on causes and consequences of depressive symptoms. It includes two factors: reflection and brooding.
- *Emotion Regulation Questionnaire* (ERQ, 10 items [α = .76]; [84]). It measures two emotional regulation strategies: reappraisal and suppression.
- *Attentional Control Scale* (ACS, 20 items [α = .84]; [85]). It assesses perceived ability in executive control over attention.

Mindfulness-based stress reduction program (MBSR)

The MBSR programs was implemented at a university-associated center specialized in MBI. MBSR instructors were highly experienced and all were certified by the University of Massachusetts Center for Mindfulness (https://www.umassmed.edu/cfm/). Each instructor had more than 6 years of teaching experience and had conducted a minimum of 30 MBSR programs.

The MBSR program [86] consisted of 32-hour training across eight weeks, including a 3-hour initial orientation session, 7 weekly 2.5-hour of face-to-face sessions, an 8-hour intensive day of practice, 45 minutes of daily home formal and informal practices and a final 3.5-hour session. Training was conducted in groups of 20–30 participants. During the program, different mindfulness practices are performed, including focused attention on the breath, open monitoring of awareness in body-scanning, prosocial meditation (i.e. loving kindness and compassion) and gentle hatha yoga. To support the practice, each participant was given a set of pre-recorded audio files to guide daily practices and a MBSR Workbook. Program adherence was supported through regular group supervision meetings.

Data analysis

Data preprocessing and univariate statistical test

Data pre-processing, analyses of missing data and imputation methods were conducted with the SPSS v. 22. All the network analyses were carried out with R v. 3.3.1 and Matlab R2017b.

Following CONSORT guidelines [87], Intent-To-Treat (ITT) analyses were carried out following Newman's guidelines [88]. Maximum Likelihood (ML) estimation was performed via Expectation Maximization imputation (EM) using SPSS v.22 software. We followed the procedure proposed by Hair and colleagues [89] to treat missing data. We first tested for both the recommended limits of missing measures [90], with a 10.8% of overall missing values and their random patterns using a Little MCAR test ($\chi2$ (1674) = 356.45, $p > .05$), concluding that missing data were completely random. To examine whether missing data could be predicted by other variables (attrition bias) a logistic regression was carried out by including clinical (DASS-21 stress, anxiety and depression symptoms), demographic (gender, age, education), and meditation experience (meditation practice and years of experience). Only the stress score at baseline was weakly associated with greater likelihood of post missing data (R2 de Cox- Snell = 0.07; R2 de Nagelkerke = 0.10). However, the correlation between stress and likelihood of missing data wasn't significant. None of the included variables predicted missingness. Finally, Maximum Likelihood estimation (ML) was performed, and Sensitivity Analysis compared the results of the completers to the estimated values was carried out, concluding that ML estimation would not lead to biased estimations.

All measures were statistically compared (pre versus post) using a Student t-test with SPSS as showed in Table 2.

Network analysis

NA was conducted to analyze the multiple relations (edges) between different psychological constructs (nodes) simultaneously, and how those relations would be reorganized after the MBSR. The successive steps procedure proposed for network analysis in psychology [91] was followed. Analyses were conducted adapting this procedure to our objectives: 1) pre and post MBSR network estimation; 2) pre and post MBSR network inference (topological characterization); and 3) pre and post MBSR network node communities analysis.

a) MBSR network estimation

The MBSR networks structure were estimated by using Gaussian Graphical Model (GGM) [92], a Regularized Partial Correlation Network (RPCN). Although the use of partial correlation in psychology has been recently questioned [93], this type of correlation has been typically used as a way to reduce spurious associations between variables. Due to the ordinal nature of the variables, a Spearman correlation matrix was used as input for the GGM (for a recent tutorial see: [94]). A network structure was estimated with the 25 nodes representing constructs associated to mindfulness training (Table 2) which resulted in 300 potential no symmetric connections (edges) among these nodes [([k*k−1]/2, being k the number of nodes], which can be either positive or negative depending on the direction of the correlation.

A RPCN has two important features. First, each edge represents partial correlations between nodes (conditional dependence relations). Thus, an association between two nodes indicates that they remain conditionally dependent after controlling for all other associations among the rest nodes in the network. If no edges emerge between two nodes, which means that the nodes are conditionally independent after controlling for the associations among all other nodes. Second, this procedure included the network regularization [95], a statistical strategy that uses a least absolute shrinkage (LASSO) correction to shrink connections in the network and sets small connections to zero. LASSO allows to reduce the number of false positive correlations within networks, which avoids spurious connections between nodes and facilitates the interpretation of the network structure [96]. The Parcor R-package [97] was used to implement the adaptive LASSO approach. The results were visualized using the *q-graph* Rpackage [98] and the *Fruchterman-Reingold algorithm* [99] to draw close those nodes with stronger and/or more connections and in the periphery those with low centrality. In order to quantify visually–based inferences of network architecture, we used the find-path algorithm (implemented in Matlab toolbox). In this algorithm, paths are defined as a sequence of linked nodes that never visit a single node more than once. Also, considering that our proposed 'psychonectome' included five general psychological constructs, it was thought that a network visualization using Principal Components Analysis, could be appropriate as an alternative parsimonious visualization method (see S1 Fig).

b) MBSR network inference (topological characterization)

In this second step, we computed different centrality parameters for the pre and post MBSR networks, as well as predictability analysis. Also, centrality plots were calculated, displaying the centrality of each node in the network. All centrality measures represent the connectedness of a given node with all other nodes in the network, assuming that highly connected nodes are usually more relevant in the network. There are some controversies on the adequacy of classical centrality indexes. For instance, strength, which is a commonly used centrality measure, is the sum of the absolute weights connected to each node, meaning that nodes with high strength are strongly or highly associated with other nodes in the network. Yet, these indexes are calculated based on the absolute values of edge-weights, which may distort the conclusions on the network structure, if there are negative relationships between nodes [100]. In our MBSR networks, mindfulness, compassion and well-being are expected to have negative relationships with psychological distress and most of psychological functioning nodes. To address this limitation, instead of strength we have included the node's Expected Influence index (EI) [100], using *expectedinf* function from the R-package *networktools* [101]. EI is a new measure of node importance, being the sum of both positive and negative weights between a node and all other nodes in the network. Also, given the lack of reliability of other centrality indexes (e.g., betweenness and closeness) [102,103] we included other centrality measures: a) *Degree*: the number of connections per node. According to the degree, hubs are defined as those nodes with the highest degree; b) *Clustering*: it measures how close a node is to the other network nodes, sharing a clustering. High clustering means that a node's neighbors are neighbors between them; c) *Efficiency*: The global efficiency is the average of inverse shortest path length and is inversely related to the path length.

Predictability of nodes in the network was estimated using the R package *mgm* [104]. Predictability is an additional network measure, defined as the degree to which a given node can be "predicted" by all other nodes in the network. Whereas centrality parameters provide relative measures of interconnectedness, predictability can be considered an absolute measure of interconnectedness (i.e., how much variance of a node can be explained by other nodes in the network)–(S1 and S3 Figs in Supplementary materials). Finally, networks accuracy (i.e. resistance to sampling variation) and stability (i.e. whether the network interpretation remains stable with less observation) were calculated using R-package *bootnet* [94]–see S4 and S5 Figs in Supplementary materials.

c) MBSR network node communities

Finally, one way to analyze the reorganization of constructs (Table 1) can be done by means of the *community analysis* of the graph. A community is defined as a set of nodes that cluster more strongly amongst each other than with other nodes of the network. The network perspective explains such communities as a result of increased mutual influences among nodes in a given cluster. The community structure was explored using the Spinglass algorithm [105], with the R package *igraph* [106]. The following parameters were used: $\gamma = 1$, start temperature = 1, stop temperature = .01, cooling factor = .99, spins = 25.

Results

Pre-post psychological changes (Hypothesis 1)

To analyze the effects of the MBSR program on the constructs selected, a standard analysis of pre-post mean differences was performed. Table 2 lists the means score and standard deviation for each variable as well as the significant differences found. As it was hypothesized, there was a significant change in most of the dependent variables measuring mindfulness, compassion towards others and oneself, psychological well-being, and emotional and cognitive functioning, as well as a significant reduction of psychological distress. Thus, the MBSR program was effective in changing the psychological state of participating individuals as confirmed by standard statistical procedures, which is a common result in MBSR programs. The rest of the analyses conducted and reported in the next sections were aimed to go beyond this standard analytic strategy by using network analysis procedures.

Table 2: Paired comparisons of pre-post measures in the constructs assessed in the MBSR program.

	Pre		Post		
Node/Construct	**Mean**	**SD**	**Mean**	**SD**	$t_{(181)}$
Mindfulness					
FFMQ-Observing	3.42	0.80	3.89	0.70	-10.19*
FFMQ-Describing	3.46	0.75	3.73	0.66	-6.40*
FFMQ-Acting Awareness	2.82	0.74	3.31	0.69	-10.47*
FFMQ-Non Judgment	3.40	0.90	3.97	0.69	-10.04*
FFMQ-Non Reactivity	2.96	0.60	3.49	0.62	-11.38*
NAS	4.25	0.76	4.68	0.71	-8.84*
EQ	3.23	0.58	3.79	0.59	-13.63*
MAIA	2.76	0.75	3.47	0.64	-16.91*
Compassion					
SCS- Self Kindness	5.96	1.82	7.38	1.57	-11.71*
SCS- Common Humanity	6.14	1.60	7.45	1.42	-11.42*
SCS- Mindfulness	5.94	1.60	7.59	1.45	-15.29*
CSP	4.26	0.45	4.35	0.42	-4.22*
IRI-Empathic Concern	28.24	4.13	28.35	3.91	-0.49
Psychological well-being					
SWLS	22.30	6.34	24.03	5.92	-6.67*
LOT	21.75	4.21	23.00	3.81	-5.85*
PHI	77.18	17.00	84.70	16.32	-8.51*
Psychological Distress					
DASS-Depression	0.60	0.59	0.32	0.35	7.36*

DASS-Anxiety	0.51	0.50	0.38	0.34	4.29*
DASS-Stress	1.15	0.59	0.76	0.46	9.50*
Emotional and Cognitive Control					
WBSI	32.54	8.10	28.79	7.94	7.56*
RRS-Brooding	9.80	3.16	8.39	2.37	7.72*
RRS-Reflection	10.88	3.03	10.32	3.03	3.13*
ERQ-Reappraisal	27.90	6.92	28.76	6.49	-1.83
ERQ-Suppression	11.20	5.17	10.08	4.52	4.22*
ACS	2.87	0.40	3.00	0.37	-5.59*

Notes: * = p < .001; Note: SD = standard deviation. The comparison remains significant after applying the Bonferroni correction for multiple comparisons (i.e., p < .002). Description of the variables and their acronyms is shown in Table 1.

MBSR network estimation (Hypothesis 2)

Before inferring the network reorganization after the MBSR, the network architecture in both pre- and post-intervention was analyzed. The pre and post MBSR regularized partial correlation networks are presented in Fig 2. Of all the possible 300 edges, 43.67% and 40.67% were estimated to be different from zero in pre- and post-assessments, respectively, which means that neither an all-to-all network nor a disconnected topology was found.

A path is defined by the sequence of links between constructs and the corresponding strength of the dependence (shown here in parenthesis). Using a find path algorithm, three paths were identified in the pre-MBSR network (displayed in different colors in Fig 2, panel C and panel D):

1) A first path was found crossing transversely the network (shaded in yellow in Fig 2, Panel C). This path was formed by mindfulness and self-compassion measures: FFMQ-O— MAIA (0.33), MAIA—EQ (0.29), EQ—NAS (0.22), NAS—SCS-M (0.23), SCS-M—SCS-A (0.25), SCS-A—SCS-H (0.22).

2) A second path included clinical symptoms and rumination measures (shaded in red in Fig 2, Panel C): DASS-A–DASS-S (0.45), DASS-S–DASS-D (0.18), DASS-D–RRS-B (0.20), and RRS-B–RRS-R (0.21).

3) A third path included the rest of mindfulness measures and the self-reported attentional control measure (shaded in blue in Fig 2, Panel C): FFMQ-D–ACS (0.28), ACS–FFMQ-A (0.27), FFMQ-A–FFMQ-J (0.18).

Interestingly, some strongly related dyads (i.e. pairs of highly related constructs that are less dependent on the rest of the network) were also found. One dyad was related to self-compassion measures (IRI-E–CSP (0.34), whereas the rest were composed by measures related to distress and/or well-being: PHI–SWLS (0.42), DASS-S–DASS-A (0.45), WBSI—FFMQ-J (-0.20), and PHI—DASS-D (-0.19).

In regard to the network configuration after the MBSR, the three paths observed in the pre- MBSR network disappeared. Instead, the post-MBSR network appears reorganized in a different manner, emerging two visually differentiated sub-networks (see Fig 2) which were further mathematically explored (see the following Results section). A close inspection of the Fig reveals that in the upper half part of this post-MBSR network (shaded in red in Fig 2, Panel D), it appeared a subnetworks of nodes that are mostly related to psychopathological constructs [i.e. stress (DASS-S), anxiety (DASS-A), depression (DASS-D); thought suppression (WBSI); emotion suppression (ERQ-S); and rumination-brooding (RRS-B)]. In the lower area of the network (shaded in purple in Fig 2, Panel D), a second subnetwork emerged in which most of the nodes are adaptive psychological constructs (i.e. mindfulness, attentional control, selfcompassion, compassion and psychological well-being). Thus, the overall reorganization of the networks indicates that the nodes of the different sets of measures were rather scattered or disconnected at pre-MBSR whereas, at post-MBSR, the nodes seem to be more closely reorganized.

Other six network features are noteworthy: 1) a psychologically interesting feature was that the "reappraisal" component of "Emotional Regulation Questionnaire" (ERQ-R; an adaptive emotional regulation strategy) was related to rumination (RRS-R), thought suppression (WBSI) and non-reactivity (FFMQ-R) at pre-MBSR; however, after the MBSR, reappraisal was related to mindfulness (EQ, FFMQ-R and FFMQ-O) and well-being measures (PHI); 2) in regard to the "suppression" component of "Emotional Regulation Questionnaire" (ERQ-S; a non-adaptive emotional regulation strategy–see [107]), which was with thought suppression (WBSI), depression (DASS-D) and Empathic Concern (IRI-E) after the MBSR, and maintained maintaining their negative relationships with compassion to others (CSP) and describing (FFMQ-D); 3) something similar happened with the "reflection" component of Ruminative Responses Scale (RRS-R; a short and mid-term adaptive strategy), which established positive relations with the describing facet of mindfulness (FFMQ-D) and attention control (ACS) after the MBSR;

4) another interesting feature was that the self-compassion measures (SCS) were quite disconnected from the well-being measures (PHI, SWLS and LOT) before the intervention but established strong connections after the MBSR; 5) in the same way, optimism (LOT), a variable that was quite disconnected from the rest of well-being measures (general well-being [PHI] and life satisfaction [SWLS]) before the intervention, increased its relations with them and with self-compassion after the MBSR; and 6) in post-MBSR network the thought suppression node (WBSI) established strong positive relations with other nonadaptive or psychopathological elements, such as emotional suppression (ERQ-S), brooding (RRS-B) and anxiety (DASS-A).

MBSR network inference (topological characterization) (Hypothesis 3)

The Expected Influence (EI) and strength of all psychological constructs were calculated (see Fig 3). The constructs with the highest EI scores, both at pre- and post-MBSR were: mindfulness measures such as non-react (FFMQ_R), interoceptive awareness (MAIA), nonattachment (NAS), decentering (EQ), self-compassion mindfulness (SCS_M) and the overall well-being measure (PHI). Only in four nodes [brooding (RRS_B), reflection (RRS_R), non-judgment (FFMQ_J) and emotional regulation-reappraisal (ERQ_R)], there was a discrepancy between EI and strength indicating that in those nodes there were many negative edges. No major changes were observed after the MBSR in either EI or strength.

In addition to EI, other centrality measures were calculated (see Fig 3): a) *Degree*: the analysis of hubs, defined as sets of nodes with the highest degree, indicated a pattern highly consistent with the results on EI and strength, with the exception of optimism (LOT), which showed a high number of relations (i.e. degree), but with low weights (i.e. low EI and strength); b) *Clustering*: nodes with the highest topological change were common humanity (SCS_H), compassion to others (CSP), depression (DASS_D), thought suppression (WBSI), and attentional control (ACS); c) *Efficiency*: nodes with the highest changes in efficiency were thought suppression (WBSI), attentional control (ACS), and reflection (RRS_R). It must be noted that nodes with highest changes in either clustering or efficiency are interpreted as having a key role in the network reorganization.

Figure 2. Network representations in pre (left panels A and C) and post (right panel B and panel D) MBSR intervention. A network is graphed by nodes (circles representing the constructs assessed in the MBSR program, described in Table 1 and named in Table 2) and edges (lines representing the statistical correlation between nodes as described in Methods section). Blue edges represent positive relationships and red edges represent negative relationships. The spatial position of nodes is chosen by the Fruchterman-Reingold algorithm to draw close those nodes with stronger and/or more connections while it places in the periphery nodes with low centrality. A) Regularized partial correlation networks pre-MBSR and B) post-MBSR intervention. The figure also shows paths, defined as a sequence of linked nodes that never visit a single node more than once, in pre-MBSR (panel C) and post-MBSR (panel D).

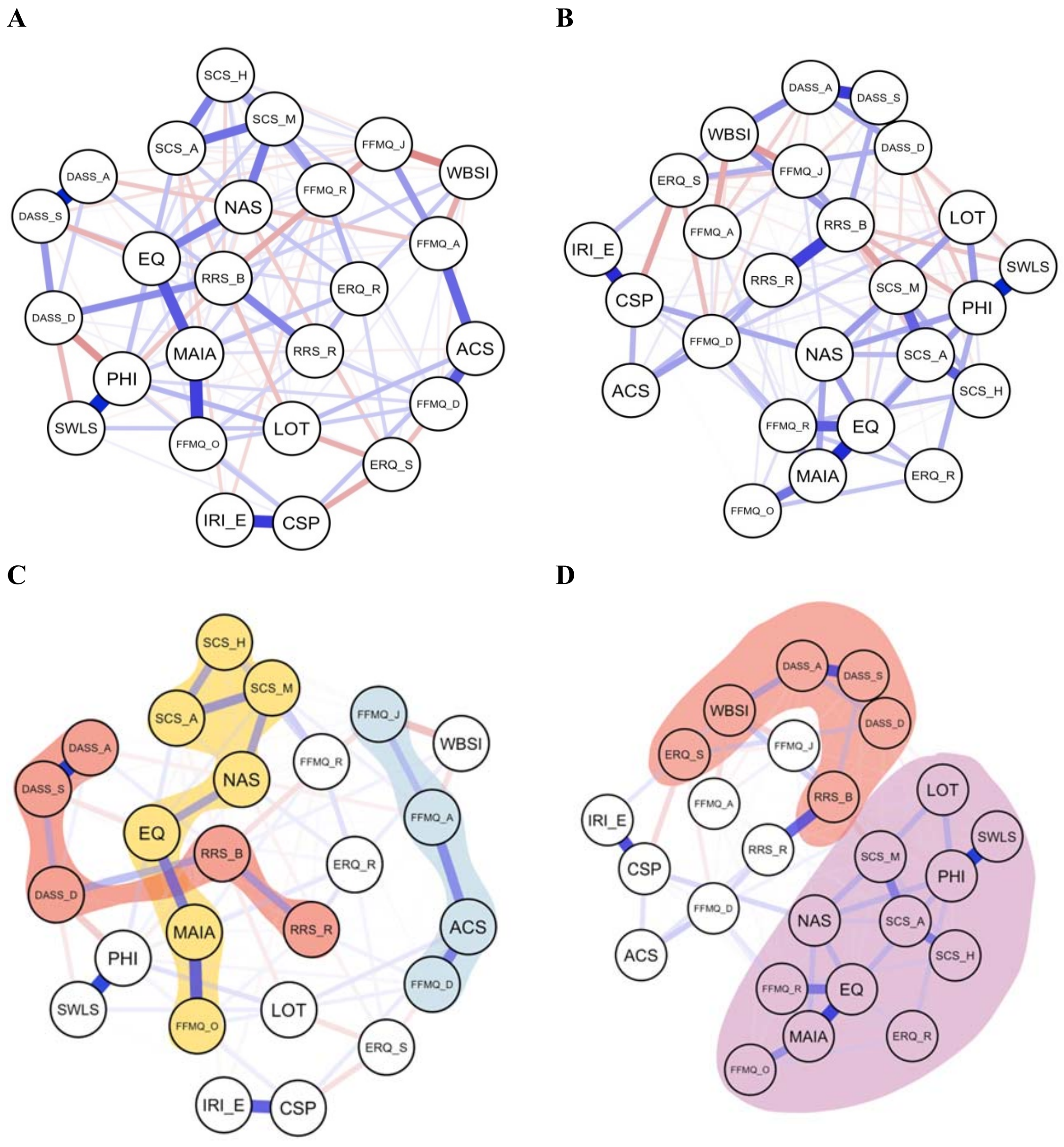


Figure 3. Topological characterization of pre- and post-MBSR intervention networks for Expected Influence and Strength. Constructs theoretically associated with MBSR are grouped according to classification given in Table 1. Each measure estimates the topological role of each node (xaxis, described in Table 2) in the network. A) Expected Influence: the sum of both positive and negative weights between a node and all other nodes in the network (nodes with high EI are positively strongly associated with other nodes in the network); B) Strength: sum of the absolute weights of all edges in the network involving that node (nodes with high strength are strongly associated with other nodes in the network); C) Degree: number of connections per node (the higher the degree, the more connected the network is); D) Clustering: closeness of a node to the other network nodes, sharing a clustering (high clustering means that a node's neighbors are neighbors between them); E) Efficiency: average of inverse shortest path length (which is inversely related to the path length).

Pre-post MBSR predictability values for each node are presented in Supplementary materials (S2 and S3 Figs). The average predictability in both networks was similar, rating from 0.55 (pre-MBSR) to 0.57 (post-MBSR), indicating that an overall average of 56% of the variance of a node was predicted by its neighbors at both moments of assessment. As compared to other network studies in psychology, following the criteria suggested by Haslbeck & Fried [104], the overall predictability was high. Also, additional analyses on the pattern of correlations between pre- and post-MBSR interventions on strength and degree, clustering and efficiency (see Supplementary Materials, Network inference) seemed to indicate that that there was a genuine network reorganization of psychological constructs after MBSR intervention.

MBSR network node communities (Hypothesis 4)

Fig 4 shows the results of the Community Detection analysis. The Spinglass algorithm detected six node communities in pre-MBSR network and five node communities in post-MBSR network.

Six meaningful communities or clusters emerged in pre-MBSR network:

1) The largest cluster (Cluster B in blue in figure 4), included 8 nodes that reflected psychological distress (anxiety [DASS-A], stress [DASS-S], and depression [DASS-D]) and emotional and cognitive control measures (brooding [RRS-B], reflection [RRS-R], reappraisal [ERQ-R], emotion suppression [ERQ-S] and thought suppression [WBSI]).

2) The second largest cluster F, depicted in red, included 7 nodes which all reflected mindfulness (decentering [EQ], non-attachment [NAS], non-reactivity [FFMQ-R], non-judgment [FFMQ-J] and mindfulness [SCS-M]) and self-compassion measures (common humanity [SCS-H] and self-kindness [SCS-A]).

3) The third largest cluster A (depicted in orange) included 3 nodes which integrates the well-being measures (general well-being [PHI], life satisfaction [SWLS] and optimism [LOT]).

4) The fourth largest cluster C (depicted in green) also include 3 nodes with other mindfulness measures (acting awareness [FFMQ-A], describing [FFMQ-D] and attentional control [ACS]).

5) Finally, two small clusters were found:

a. Cluster E (depicted in purple) composed by the rest of mindfulness measures (interceptive awareness [MAIA] and observing [FFMQ-O]).

b. Cluster D (depicted in yellow) composed by compassion measures (compassion to others [CSP] and empathic concern [IRI-E]).

These six large clusters were reorganized at post-MBSR, generating a 5-cluster final organization:

1) The mindfulness and self-compassion measures that were scattered in clusters F, C and E in pre-MBSR network, were reorganized in two big clusters after the MBSR:

a. Cluster B (in blue) included non-attachment [NAS], self-compassion [SCS], non-judgment [FFMQ-J] and acting awareness [FFMQ-A].

b. Cluster E (depicted in purple) included decentering [EQ], interoceptive awareness [MAIA], non-reactivity [FFMQ-R], observing [FFMQ-O] and reappraisal [ERQ-R].

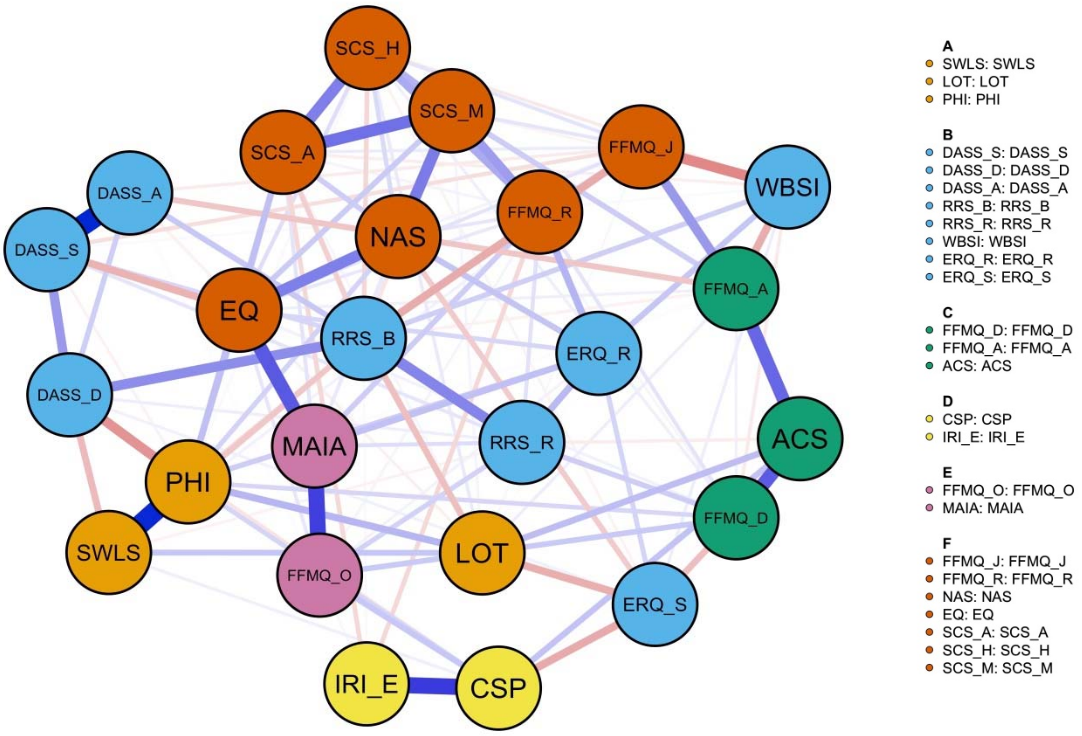
2) The Psychological distress and Emotional and cognitive control measures remained grouped in the same cluster D (depicted in yellow), with the exception of emotional reappraisal [ERQ-R].

3) Well-being measures remained all together in orange cluster A (general well-being [PHI], life satisfaction [SWLS] and optimism [LOT]).

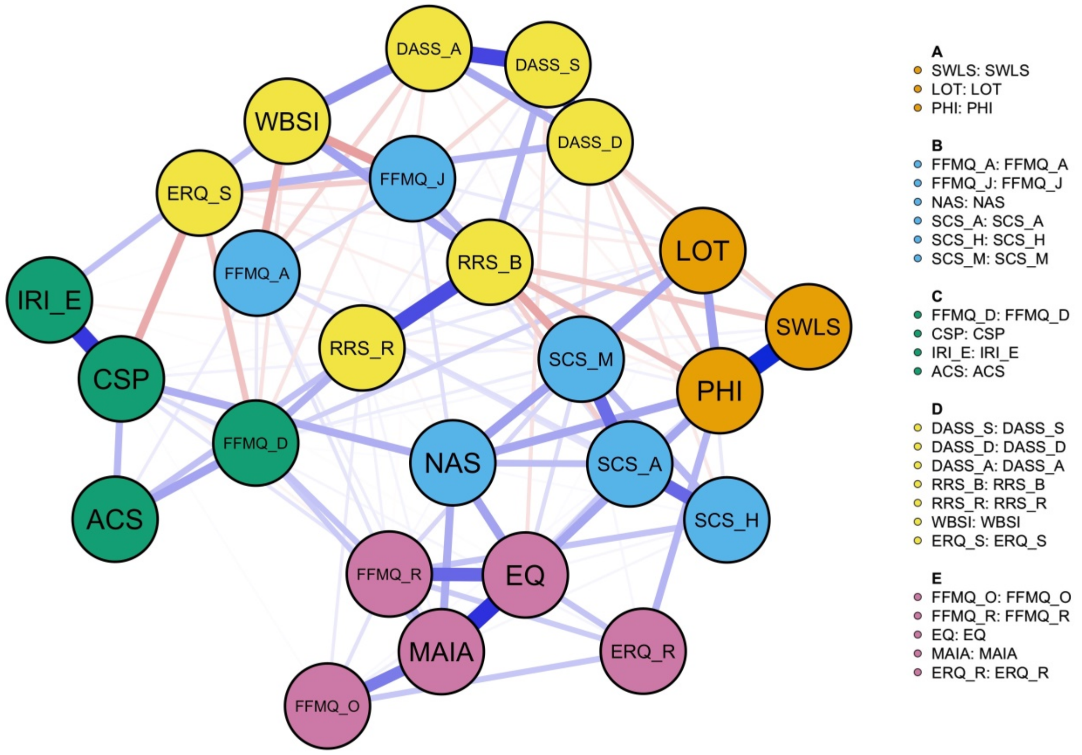
4) Finally, a mixed cluster C (depicted in green) was found, including compassion to others measures [CSP and IRI-E], attentional control [ACS] and describing [FFMQ-D].

Figure 4. Results of the community detection analysis performed on the network shown in Fig. 1. The identified communities depict the variables that more strongly inter-correlated.

A-. Communities in pre-MBSR network



B-. Communities in post-MBSR network



Discussion and conclusions

The current study belongs to the growing body of scientific literature using NA to explore alternative theoretical and empirical conceptualizations in psychological science [15,108]. Based on that background, we propose the '*psychonectome'* concept, defined as a complex ensemble of dependences between psychological constructs, where the focus of interest is transferred from the changes in individual constructs to the relation between them. The underlying principle for this proposal is that the functioning of the mind is viewed as a complex network of interrelated psychological constructs. As far as we know, this is the first empirical study using NA to explore the effects of a standardized mindfulness intervention (MBSR) on the reorganization of psychological constructs that are central to that practice.

Based on the extant evidence on the effects of MBSR programs [48–50], the first hypothesis of the study stated that the MBSR would yield significant adaptive changes by increasing mindfulness, compassion, well-being, emotion and attention regulation scores and reducing psychological distress and rumination. Using standard univariate statistics, the results consistently confirmed the first hypothesis. The MBSR yielded significant change in almost all the dependent variables selected in the expected direction. Yet, this analytic approach does not facilitate to inquire about the action mechanisms involved in the psychological changes produced by the practice of MBSR, which is something necessary to keep moving forward in this area [109].

To overcome such analytic limitations, the second hypothesis of the study, based on a network analysis approach, was that participating in MBSR would reorganize the network topology. Our results identified three main paths in the pre-MBSR network (i.e. mindfulness and self-compassion; clinical symptoms and rumination; and most of FFMQ mindfulness components with attentional control measure). Yet, these three paths disappeared at post-MBSR network, and instead, a new reorganization appeared with two distinct visually differentiated sub-networks (see Fig 1). In the upper half area of this post-MBSR network, most of the nodes were related to psychopathological constructs, while in the lower area of the network, most of the nodes were related to adaptive psychological constructs. As we must be cautious when visually interpreting networks [110], we further explored this network reorganization mathematically by means of community analysis (hypothesis four).

Specifically, three network reorganization features are especially noteworthy: First, although compassion (to both self and others) is an attitudinal foundation of mindfulness practice [86], and self-compassion is a significant predictor of therapeutic change in MBIs [111], these components are implicitly, but not explicitly, taught in MBSR practices [112] and it is questioned whether or not they should be an ingredient of these practices [113]. Our results showed that, while self-compassion elements were relatively disconnected from well-being measures before MBSR, they became strongly connected after the intervention. Furthermore, community analysis detected that, after the MBSR, self-compassion measures behave similarly to some mindfulness constructs, such as non-attachment and non-judgment. These NA-based results suggest that self-compassion is, indeed, an important variable, and may deserve to have a more active role in mindfulness programs.

A second interesting aspect of the network reorganization is related to emotion regulation processes. Mindfulness interventions have been particularly effective in promoting adaptive emotional regulation strategies [55], especially in affective disorders such as depression or anxiety [114]. Current findings indicate that mindfulness practice would facilitate the cognitive reappraisal of negative experiences and savoring of positive ones [115]. Consistent with the emphasis placed on emotional regulation process in mindfulness programs, we found that, while cognitive reappraisal was related to rumination, thought suppression, and non-reactivity at pre-MBSR, it was related to mindfulness and well-being measures post-MBSR, thus belonging to a more naturally adaptive cluster of nodes. Furthermore, community analysis detected that, after the MBSR, cognitive reappraisal was clustered with some mindfulness measures, such as decentering, interoceptive awareness, and observing. These results emphasize the importance of cognitive aspects of emotion regulation [116] as a key mechanism of MF interventions, which enriches our understanding of mindful-emotion regulation processes [117].

A final observation on the pre-post reorganization of constructs is related to well-being. Different psychological traditions emphasize the importance of consciousness in well-being promotion [118]. In this sense, mindfulness practice may promote well-being through a better awareness of basic psychological needs [119]. Current studies indicate that mindfulness training mediates positive well-being outcomes [120] and our NA supported these findings. Our results indicated that while well-being measures were quite disconnected from each other before the intervention, they increased their mutual relations after the MBSR, enhancing their relations with self-compassion and mindfulness nodes. Furthermore, network inference of centrality parameters showed that general well-being was one of the most central nodes in the network both before and after MBSR. Finally, community analysis detected a distinctive “Psychological well-being” cluster that included general well-being, life satisfaction and optimism both before and after MBSR. Summarizing, this NA seems to indicate that well-being, which is one of the main motivation of participants in meditation training [121], is one of the key component in MBSR and, according to other studies, it could be a factor that triggers cognitive changes in the process of MF trainings [122]. Thus, this psychonectome perspective provides new insights on the central of role psychological well-being in mindfulness.

The third hypothesis stated that, compared to the pre-MBSR state, mindfulness, emotion regulation and well-being constructs would increase their centrality in the resulting post- MBSR psychonectome. Consistent with previous theoretical models of mindfulness functioning [52], Expected Influence and Strength centrality indexes revealed that some measures of mindfulness (i.e. non-reactivity, interoceptive awareness, non-attachment, decentering and mindfulness self-compassion) were the most central in the networks both before and after the MBSR, together with a general well-being measure. Furthermore, emotional reappraisal and reflective cognitive style also emerged as central nodes in Expected Influence analysis. On the other hand, the nodes with the highest topological change after the MBSR were attentional control, compassion measures, depression and thought suppression. Centrality can be considered an indirect indicator of clinically-significant changes as it is assumed that highly central constructs can influence other nodes in the network [123]. Although there are some concerns about which could be the best central indices in behavioral research [102,103], if the assumption is correct, the design of health promotion strategies and treatments should consider the convenience of prioritizing interventions on these central nodes [123,124]. Based on our centrality results, it could be hypothesized that MBSR interventions should focus on increasing trait-mindfulness levels and attentional control skills, together with compassion elements, and enhancing positive emotional regulation strategies, whereas they should reduce rumination tendencies. Enhancements in these elements seem to be topologically connected to well-being components. Although peripheral nodes are also relevant in the network, the centrality analyses suggest that intervening on the most central nodes might have stronger and faster dispersion to the whole system than intervening on peripheral ones [125]. Further empirical research should directly target these innovative variations in MF interventions.

It is important to consider that, according to stability analysis, our MBSR network interpretations were reliable, and our centrality indexes and the network interpretation would remain stable and accurate in samples with fewer observations. Furthermore, predictability analysis also suggested that the overall predictability was quite high in both pre- and post-MBSR networks.

Finally, the fourth hypothesis of the current study was that MBSR would have an effect in regrouping the constructs into psychologically meaningful sub-networks. As a previous requirement for the interpretability of network changes, several analyses showed that there was true reorganization of the networks (see Supplementary materials), which provides robustness to the findings. Community analysis detected six node communities in pre-MBSR network and five node communities in post-MBSR network, thereby showing that the network was reorganized after the MBSR program. Specifically, whereas the pre-MBSR communities were composed by rather heterogeneous elements corresponding to different families of constructs (e.g. mindfulness and self-compassion constructs were scattered in different clusters in pre-MBSR network), the communities of constructs that emerged after the MBSR seemed to be reorganized in a more psychologically meaningful mode. Interestingly, this new reorganization corresponded more closely to the a priori five theoretical domains of constructs that were initially selected based on the available empirical evidence (see Table 2 and Fig 3).

The study has some strengths and limitations. Some of the strengths are that is a novel study in different ways. As far as we know, this is the first empirical study using NA to explore a standardized mindfulness intervention and we took this opportunity as a proof-of- concept of the '*psychonectome*', using psychological constructs instead individual items (e.g. symptoms). It also included, in the same design, a variety of a comprehensive list of constructs that the literature has found to be relevant for the practice of meditation. Also, the analyses conducted in the study have included some of the most recent procedures proposed to analyze and visualize networks in Psychology (e.g., Expected Influence as a measure of centrality, which seems more adequate than others, like strength, or Predictability, to analyze the explained variance of each node in the network) and incorporate some additional indexes and analyses (e.g., Efficiency and clustering), that are typically used to analyze brain activity [36].

Yet, these initial results must be considered in the light of some methodological limitations. First, our sample consisted of general population individuals voluntarily attending a MBSR course. As an important aspect of meditation practice is to be motivated to engage in its practice [52,69], the lack of random allocation to the treatments is an acknowledged limitation in this field of research [126–128]. A second limitation was that we included both, participants with and without previous meditation experience from different traditions, which might be a relevant moderator of our results [44]. Given the novelty of our study, our goal was to examine how a mindfulness intervention, in general, would impact on the relations between different psychological constructs from a psychonectome perspective. Future studies should compare the network reorganization between different meditation practices (e.g. mindfulness vs. compassion meditation), between different meditation experience (e.g. novices vs. experts), and should include a control group. A third limitation is that only self-reported measures were included in the networks. Future studies should include other types of elements like observable behaviors [129], biological parameters [125], performance in cognitive experimental tasks [130], or even external factors to the network as, for instance, life stressors [14]. Including further relevant information in networks might shed light on the action mechanisms underlying the practice of meditation and, in general, any intervention. A fourth limitation is that only pre and post information was included. Future studies on networks analysis within this field should consider adding longitudinal data from inter-session measures and follow-ups, as it has already been done in MBSR interventions [122], to infer causality in the psychonectome [131,132]. Finally, it should be also taken into account that NA methods are still relatively new in psychology and there is still no consensus on issues as relevant as the best procedure to estimate the required sample size to obtain accurate edge weights [124], the optimal analytic procedures [93,133], or the most accurate and reliable indexes of centrality [94,102,134]. More specifically, there is a current debate on the replicability of findings in NA [133,135,136]. Although replicability can be partially improved by providing R scripts and data matrices, which we have done in the present study, a recent meta-analysis found that most of the published literature in psychopathology has not done this [13]. Also, and more importantly to increase replicability, it could be possible that using only signs and symptoms in network analysis, instead of psychological constructs, may limit the statistical accuracy of the networks [22]. Yet, it is still too soon to provide definite answers on the incremental validity of NA as compared to more traditional ways of analyzing the relationships between psychological attributes [21,22].

Despite these limitations, this study provides some novel results on the complex multivariate interaction of the variables involved in mindfulness practice which is revealed by network analysis. Beyond these specific results, the current 'psychonectome' proof-of-concept approach seems useful to provide further evidence of the mind as a complex network of psychological constructs. Considering topological aspects of the relations between constructs may help to enhance our understanding of psychological functioning as a complex network of interacting elements that are mutually interconnected [18–20,137,138]. This unique perspective has become central to fields like neuroscience [25,35] and may also provide useful insights on the functioning and mechanisms of human mind.

Supporting information

S1 Fig. Principal components analysis network configurations of Pre- (panel A) and Post-MBSR intervention (panel B). (TIF)

S2 Fig. Pre- (panel A) and Post-MBSR intervention (panel B) predictability. (TIF)

S3 Fig. Pre- and Post-MBSR intervention predictability scores (i.e., percentage of variance for each node of the network). (TIF)

S4 Fig. 95% bootstrapped CIs around each edge-weight for the estimated networks of pre- MBSR (left) and post- MBSR (right). (TIF)

S5 Fig. Pre-MBSR (Panel A) and post- MBSR (Panel B) stability of centrality indices, showing an average correlation between the centrality indices of the original sample with people dropped. (TIF)

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The impact of compassion meditation training on psychological variables: A network perspective

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Abstract

Objectives: We aimed to examine how a standardized compassion meditation program would induce changes in the patterns of interactions among psychological variables. **Methods**: We conducted network analyses on psychological variables before and after 96 participants completed an 8-week Compassion Cultivation Training (CCT) program. **Results**: After the CCT program, self-compassion variables increased their importance and influence in the network (i.e. centrality), whereas psychopathology and negative functioning variables (e.g. stress, anxiety, depression, and rumination) decreased their centrality. More importantly, self-compassion increased its associations with other adaptive variables (e.g., emotional reappraisal and mindfulness) after the program. Also, self-compassion, non-attachment, and decentering were the nodes connecting different subnetworks (i.e., bridge nodes), decoupling psychopathological variables (i.e., psychological distress and rumination) from the rest of the network. The variance of compassion, mindfulness, and well-being was mostly explained by other nodes in the network (i.e., predictability), whereas psychopathology-related constructs diminished in their predictability after the program. **Conclusions**: These results highlight the role of self-compassion and other adaptive variables as the key mechanisms through which compassion meditation may produce its effects.

Keywords: compassion; meditation; Compassion Cultivation Training; CCT; mechanisms; network analysis.

Compassion has long been a fundamental value in Eastern contemplative traditions, yet only in the last two decades has it received scientific interest (Gilbert, 2019; Kim, Cunnington, et al., 2020). Using varying definitions of compassion, researchers have studied compassion from diverse perspectives addressing its emotional component (Goetz et al., 2010), its contribution to the concept of the self (Neff, 2003b), and its motivational role (Gilbert, 2019), among others. In an attempt to integrate these perspectives, Strauss et al. (2016) identified several common themes: (1) Awareness (i.e., to recognize the suffering in oneself and others); (2) Universality (i.e., to understand that all human beings suffer); (3) Empathy (i.e., emotional resonance with the person who is suffering, connecting with their distress); (4) Acceptance (i.e., being able to tolerate one's uncomfortable feelings and thoughts in response to suffering); and (5) Motivation (i.e., to being motivated to act to alleviate the suffering). This five-factor structure has received preliminary empirical support (Gu et al., 2017).

Preliminary evidence highlights the potential benefit of compassion on a wide range of outcomes, including increases in brain plasticity (Klimecki et al., 2014), neural responses to experienced or observed suffering (Kim, Cunnington, et al., 2020), lower physiological reactivity to stress (Cosley et al., 2010), prosocial behavior (Condon et al., 2013; Luberto et al., 2018), social connectedness (Crocker & Canevello, 2008), psychopathology (MacBeth & Gumley, 2012), and well-being (Neff et al., 2007), among others.

Despite the growing interest in meditation effects, the scope of scientific research has been focused on mindfulness practice, and other forms of meditation have not received the scientific attention they deserve (Davidson & Dahl, 2018). A contemporary conceptualization distinguishes between three families of meditation practices (Dahl et al., 2015): (a) attentional family: practices used to train the self-regulation of attention and the interoceptive awareness, which would include the practice of mindfulness; (b) constructive family: practices used to cultivate psychological well-being by developing prosocial qualities and socio-emotional skills, such as compassion, kindness, equanimity and joy; and (c) deconstructive family: practices used to cultivate socio-cognitive skills by developing self-inquiry, self-knowledge and wisdom.

In regard to interventions directly or indirectly aimed at enhancing compassion, Mindfulness-Based Interventions (MBI) have been widely disseminated and scientifically assessed in recent years (Goldberg et al., 2018). In MBI, compassion is taught implicitly as an attitudinal foundation of mindfulness and is modeled by the instructors' behaviors and attitudes (Brito-Pons et al., 2018). Compassion-Based Interventions (CBIs) have also been developed, aimed at teaching compassion explicitly within a meditation framework (Kirby, 2017). Most CBIs follow highly structured formats, are time-limited, and include assessment tools to verify participants' changes. These features render them suitable for scientific evaluation. The meta-analysis conducted by Kirby et al. (2017) on compassion interventions found a moderate between-group differences on self-compassion, mindfulness, psychological distress (i.e. depression and anxiety), and well-being, even in those randomized controlled trials (RCTs) where an active control comparison group was included.

Compassion Cultivation Training (CCT), is an 8-week secular program designed to enhance compassion (Goldin & Jazaieri, 2017). Several studies, including RCTs, have found that CCT significantly promotes beneficial changes in participants from the general population such as: (1) increasing self-compassion, compassion for others and being the object of compassion for others (Jazaieri et al., 2013), and decreasing fear of compassion for self (Goldin & Jazaieri, 2017); (2) reducing stress, anxiety, and depression (Brito-Pons et al., 2018; Jazaieri et al., 2018); (3) increasing positive affect and decreasing negative affect (Jazaieri et al., 2014); (4) enhancing adaptive emotional regulation strategies such as cognitive reappraisal and reductions in emotion suppression (Jazaieri et al., 2014, 2018); (5) enhancing adaptive cognitive regulation processes (i.e., increasing mindfulness and reducing mind wandering, worry, and rumination) (Jazaieri et al., 2014, 2015); (6) increasing well-being levels (Brito-Pons et al., 2018; Jazaieri et al., 2014); and (7) promotion of caring behaviors and empathic concern (Jazaieri et al., 2015). Furthermore, CCT appears beneficial for certain populations, such as adults experiencing chronic pain (Chapin et al., 2014) and healthcare workers (Scarlet et al., 2017). Given the similarities between standardized mindfulness and compassion programs, Brito-Pons et al. (2018) analyzed the effects of CCT in comparison with a Mindfulness-Based Stress Reduction (MBSR) group. They found that both CCT and MBSR enhanced well-being, mindfulness, and compassion skills. However, the CCT intervention had a greater impact than MBSR on compassionate skills (i.e., self-compassion, empathic concern, and common humanity).

Given the growing interest on comparing meditation-based interventions, it is scientifically relevant to analyze the mechanisms of actions through which different interventions produce their effects. The increasing number of studies analyzing the mechanisms of mindfulness (Gu et al., 2015; Hölzel et al., 2011; Tang et al., 2015) contrasts with the relatively few studies on mechanisms of compassion interventions (Gu et al., 2017). Despite the general agreement on the need to increase research on the mechanisms of change in psychological interventions (Kazdin, 2009; Nielsen et al., 2018), statistical approaches to analyze those mechanisms, like traditional mediation analyses, may fail to uncover their complex dynamics (Hofmann et al., 2020). Alternatively, network analytic approaches (e.g., Borsboom & Cramer, 2013) may better characterize the complex interactions between outcomes and mechanisms involved in psychological interventions. However, with few exceptions (e.g., Papini et al., 2020), network analysis remains underused in the study of intervention-induced mechanisms of change.

In an innovative approach aimed at revealing the mechanisms of MBIs, Roca et al. (2019) used network analysis to explore whether a MBSR program can change the patterns of relations among psychological constructs. The authors found significant changes in the network topology after the MBSR program, resulting in a reorganization of the relations among the different psychological constructs. Network analysis showed that self-compassion constructs behave similarly to most mindfulness measures, becoming strongly connected with well-being after the intervention. Furthermore, adaptive emotional regulation strategies increased their connections with mindfulness and well-being measures after the MBSR. Corresponding more closely with theoretical models, community analysis revealed the following clusters: (1) a cognitively-oriented cluster of mindfulness nodes, (2) an emotionally-oriented one consisting of mindfulness and self-compassion nodes, (3) another comprising distress and cognitive-emotional dysregulation nodes, (4) one comprising well-being nodes, and (5) one consisting of nodes signifying compassion for others. Furthermore, they used this study as a proof-of-concept of the psychonectome (i.e., the idea that psychological functioning depends upon a complex dynamic ensemble of dependencies among different psychological constructs) and its utility to analyze patterns of change after interventions.

In the last decade, network analysis has been used as an innovative framework to understand psychopathology (Borsboom & Cramer, 2013; McNally, 2016). In contrast to both categorical and dimensional traditional diagnostic models, the network approach does not conceptualize the symptoms as reflective of underlying disorders. Rather, it views episodes of mental disorder as emergent (not "underlying") phenomena arising from interactions among their constitutive symptoms (Borsboom & Cramer, 2013). In network analysis the focus is transferred from the changes in individual variables to the relation between them, which can be especially useful in illuminating structural psychological changes after intervention programs. Psychological variables are represented by nodes (i.e., circles) and the relationship between them are represented by edges (i.e., lines connecting pairs of nodes). The edge weight represents the probability of co-activation between two nodes.

In the present study, we computed weighted, undirected networks comprising edges depicting (regularized) partial correlations between pairs of variables representing psychological constructs relevant to compassion meditation. We also computed node centrality metrics for these variables that estimate their connectedness and potential causal influence within the network. We aimed to examine how a standardized compassion program, such as CCT, would induce changes in the patterns of interactions between different psychological constructs. We had five hypotheses. First, we predicted that CCT would result in significant increases in compassion, mindfulness, well-being, and adaptive cognitive-emotional control, and significant reductions in psychological distress and non-adaptive cognitive-emotional control measures. Second, we predicted that CCT would promote a topological network reorganization such that compassion variables would increase their connections with mindfulness and adaptive emotional-cognitive regulation measures after the program. Third, we hypothesized that the centrality values for nodes signifying compassion, mindfulness, and well-being would increase following CCT, whereas those for distress and cognitive-emotional dysregulation would decline. Fourth, we expected that compassion, mindfulness, and well-being would be the more predictable nodes (i.e. the nodes for which more variance could be predicted by other nodes in the network). Fifth, we predicted that CCT would change the clustering of the measured constructs towards more meaningful communities, corresponding more closely with the five theoretical domains of constructs selected for this study according to theoretical models of compassion (Goldin & Jazaieri, 2017; Gu et al., 2017).

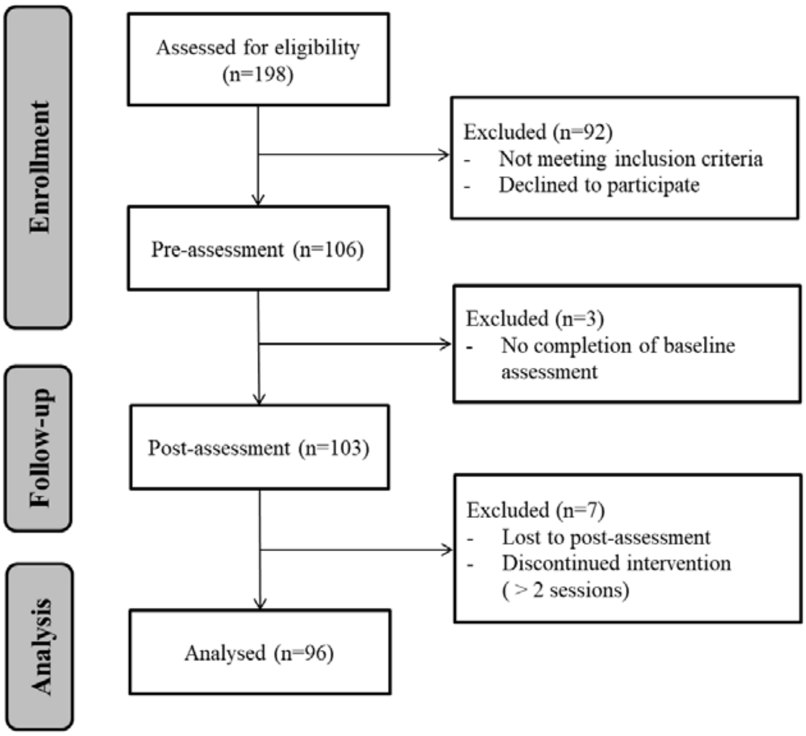
Method

Participants

Between April and December 2017, 106 participants enrolled in a standardized 8-week CCT at a university-associated research center specializing in Mindfulness and Compassion-Based Interventions. Inclusion criteria for the CCT were as follows: (1) 18 years of age or more, and (2) not having any current serious psychological disorder or substance use.

Statistical analyses were conducted only for data from participants who completed pre-assessment and attended a minimum of 6 sessions (i.e., 75% of the program). A description of the participation flow diagram is presented in Figure 1. After applying all exclusion criteria, data from a total of 96 individuals were included in all analyses. Their mean age was 47.78 (*SD*=9.80), 75% were women, 90.6% had university education, 42.7% were married, 79.2% were employed, 11.5% had a physical illness, and 85.4% had previous meditation experience (i.e., mean of 4.81 years [*SD*=5.58]).

Figure 1. Participation flow diagram.



Procedure

The study followed a pre-post design. Participants were invited to take part in the study when they registered on the official website offering the compassion program. Those who agreed to participate were administered a brief online screening questionnaire on demographics and inclusion criteria after providing written informed consent. After enrolling, participants completed an online assessment during the week before starting the program (i.e. pre-assessment) and during the week after its completion (post-assessment). The online assessment consisted questionnaires administered via Qualtrics software, which lasted approximately 45 minutes. When necessary, Qualtrics reminders were scheduled for those participants who had not completed the questionnaires. After completing the post-assessment, participants were debriefed and received an individualized report of their questionnaires scores. The research was approved by the university ethics committee prior to participant recruitment (Ref 2016/17-016) and was registered at ClinicalTrial.org (NCT03920241).

Compassion Cultivation Training (CCT)

The CCT was delivered through a university-associated center specializing in Mindfulness and Compassion-Based Interventions. The program was implemented by two highly experienced instructors, certified by the Center for Compassion and Altruism Research and Education (http://ccare.stanford.edu/) at Stanford University, with a combined teaching experience of over fifty CCTs in the last five years. Program adherence was supported through regular group supervision meetings. Furthermore, each participant received a set of pre-recorded audio files to guide the daily practices and a workbook.

The CCT is an 8-week standardized program (Brito-Pons et al., 2018; Goldin & Jazaieri, 2017) consisting of 2.5-hour of face-to-face session per week and 30 minutes of daily home formal and informal practices. Training was conducted in groups of 20-30 participants. The CCT consists of six sequential steps addressing the different components of compassion (see Table 1): (1) settling the mind and learning how to focus it; (2) practicing loving kindness and compassion for a loved one; (3) practicing loving kindness and compassion for oneself; (4) compassion toward others, embracing shared common humanity and developing appreciation of others; (5) compassion toward others including all beings; and (6) active compassion practices (*tonglen*) involving explicit evocation of the altruistic wish to do something about others' suffering. Finally, participants learn an integrative compassion practice combining the six essential elements into an integrative compassion meditation practice.

Table 1: Description of the CCT modules (adapted from Brito-Pons et al., 2019).

CCT protocol
Week 1 – Cultivating stable and focused attention through breath-focused meditation and informal practices.
Week 2 – Cultivating compassion for a loved one by learning how to identify the physical and physiological feelings of warmth, tenderness, concern, and compassion.
Week 3 – Cultivating compassion for oneself by developing self-acceptance, nonjudgment and caring oneself.
Week 4 – Cultivating loving-kindness for oneself by developing appreciation, joy, and gratitude for oneself.
Week 5 – Cultivating common humanity by recognizing our shared common humanity and the deep interconnectedness of human beings.
Week 6 – Cultivating compassion for others by moving progressively the focus from a loved one, to a neutral person, a difficult person, and finally to all beings.
Week 7 – Cultivating active compassion by evoking the altruistic wish to alleviate others' suffering through the practice of *tonglen* ("giving and taking"), a visualization where the practitioner imagines taking away the suffering of others and giving them what is beneficial in oneself.
Week 8 – Integrating compassion by practicing an integrated compassion meditation combining all the previous components.

Measures

The online assessment included questionnaires evaluating five domains considered central in psychological theories of meditation and compassion (Goldin & Jazaieri, 2017; Malinowski, 2013): mindfulness, compassion, psychological well-being, psychological distress and emotional-cognitive control. Table 2 shows a brief description of the measures as well as the internal consistency scores (i.e. Cronbach's alpha) found in this sample.

Table 2: Constructs and instruments used in the study (Roca et al. 2019).

Mindfulness

- *Five-Facet Mindfulness Questionnaire-Short Form* (FFMQ, 20 items [α = .91]; Baer et al., 2006). It includes five mindfulness skills: describing (FFMQ-D), acting with awareness (FFMQ-A), observing (FFMQ-O), non-judging of inner experience (FFMQ-J), and non-reactivity to inner experience (FFMQ-R).
- *Non-Attachment Scale* (NAS, 30 items [α = .95]; Sahdra et al., 2010). It assesses the absence of excessive fixation of thoughts and mental images, as well as the absence of the internal pressure of hold, change or avoid any experiences.
- *Experiences Questionnaire* (EQ, 11 items [α = .90]; Fresco et al., 2007). It measures the ability to observe, without attaching oneself, our feelings and thoughts.
- *Multidimensional assessment of interoceptive awareness* (MAIA, 32 items [α = .96]; Mehling et al., 2012). A measure of interoceptive body awareness.

Compassion

- *Self-Compassion Scale-Short Form* (SCS-SF, 12 items [α = .91]; Raes et al., 2011). It measures compassion to oneself through three components: mindfulness (SCS-M), self-kindness (SCS-A) and common humanity (SCS-H).
- *Compassion Scale* (CSP, 24 items [α = .90]; Pommier et al., 2019). It assesses compassion to others.
- *Interpersonal Reactivity Index* (IRI, 14 items [α = .74]; Davis, 1980). It measures empathy towards others. In this study only the Empathic Concern subscale (IRI-E) was included.

Psychological well-being

- *Satisfaction With Life Scale* (SWLS, 5 items [α = .90]; Diener et al., 1985). It measures global life satisfaction.
- *Life Orientation Test–Revised* (LOT-R, 10 items [α = .68]; Scheier et al., 1994). It measures dispositional optimism.
- *Pemberton Happiness Index* (PHI, 11 items [α = .93]; Hervás & Vázquez, 2013). It measures hedonic and eudaimonic components of psychological well-being.

Psychological Distress

- *Depression Anxiety Stress Scales* (DASS-21, 21 items [α = .95]; Lovibond & Lovibond, 1995). It assesses symptoms of depression (DASS-D), anxiety (DASS-A) and stress (DASS-S).

Emotional and cognitive control

- *White Bear Suppression Inventory* (WBSI, 10 items [α = .92]; Wegner & Zanakos, 1994). It measures the tendency to suppress unwanted intrusive thinking.

- *Ruminative Response Style* (RRS, 22 items [α = .93]; Nolen-Hoeksema & Morrow, 1991). It measures rumination through two factors: cognitive reflection (RRS-R) and brooding (RRS-B).
- *Emotion Regulation Questionnaire* (ERQ, 10 items [α = .69]; Gross & John, 2003). It measures two emotional regulation strategies: reappraisal (ERQ-R) and suppression (ERQ-S).
- *Attentional Control Scale* (ACS, 20 items [α = .71]; Derryberry & Reed, 2002). It assesses perceived ability in executive control over attention.

Note: Cronbach's alpha found in the current study.

Data analysis

Network analyses were carried out with R version 3.3.1, whereas data pre-processing, missing value analysis, imputation methods and univariate statistical test (i.e., t-tests) were conducted with SPSS v.25. Following Hair et al.'s (2014) recommendations to treat missing data, Maximum Likelihood (ML) estimation was performed via Expectation Maximization (EM) imputation. There were a 13.4% of overall missing values and none of the measures exceeded the recommended limits for missing values. A Little MCAR test ($\chi^2(1674) = 356.45$, $p > .05$) showed that the pattern of missing data was random and suitable for imputation. Finally, a Sensitivity Analysis comparing the completers to the estimated values was carried out, concluding that the ML estimation would not lead to biased estimations.

Network analysis was conducted following standard guidelines and R packages (Fried et al., 2018; Jones et al., 2019 -see technical details in the Supplementary Materials file) with the aim of: (1) analyzing the pre-post changes with univariate statistics; (2) estimating the pre- and post-CCT network structures; (3) analyzing the connections of a node with all other nodes in the network (i.e., nodes centrality); (4) calculating the amount of variance of each node statistically explained by all other nodes in the network (i.e., predictability); (5) exploring whether the network is reorganized in different clusters of nodes after the CCT (i.e., communities); (6) estimating the nodes that act as connectors between the five domains of variables included in the study (i.e., bridge centrality); and (7) the overall robustness of the results (i.e., accuracy and stability). The data are available at https://github.com/nirakara-lab/Compassion_Meditation_Training (doi: 10.5281/zenodo.3700657).

Results

Pre-post psychological changes (univariate statistics)

Consistent with previous studies, *t-tests* for repeated measures revealed significant pre-post significant increases on measures of mindfulness, compassion, well-being, and adaptive cognitive and emotional control that accompanied a significant decrease in psychological distress and maladaptive cognitive-emotional measures (Table 3).

In contrast, network analysis provides complementary information about the connections between these psychological constructs that cannot be achieved by standard univariate statistics. In network analysis the focus is shifted from the changes in individual variables to the relation between them, thereby enabling visualization of structural psychological changes after intervention programs.

Table 3: Paired t-test comparisons of pre-post measures in the constructs assessed in the CCT.

Node/Construct	Pre-CCT		Post-CCT			
	Mean	**SD**	**Mean**	**SD**	$t_{(95)}$	***d***
Mindfulness						
FFMQ-Observing	3.70	0.74	4.06	0.73	-6.43*	-.65
FFMQ-Describing	3.63	0.74	3.83	0.65	-3.07*	-.31
FFMQ-Acting Awareness	2.95	0.66	3.39	0.64	-8.09*	-.83
FFMQ-Non-Judgment	3.64	0.87	4.15	0.64	-7.24*	-.74
FFMQ-Non-Reactivity	3.20	0.57	3.59	0.50	-6.75*	-.69
NAS	4.42	0.76	4.77	0.65	-6.41*	-.65
EQ	3.33	0.56	3.82	0.50	-9.50*	-.97
MAIA	3.08	0.80	3.50	0.69	-8.08*	-.82
Compassion						
SCS-Self Kindness	6.08	1.84	7.72	1.34	-10.61*	-1.08
SCS-Common Humanity	6.15	1.65	7.71	1.43	-9.93*	-1.01
SCS-Mindfulness	6.19	1.75	7.67	1.41	-10.00*	-1.02
CSP	4.29	0.46	4.45	0.44	-5.06*	-.51
IRI-Empathic Concern	28.49	4.02	29.14	4.17	-1.93	-.20
Psychological well-being						
SWLS	23.28	6.05	24.91	5.33	-3.49*	-.36
LOT	22.75	3.66	23.84	3.54	-3.86*	-.39
PHI	79.63	17.25	87.41	14.97	-5.90*	-.60
Psychological Distress						
DASS-Depression	0.55	0.64	0.28	0.36	4.75*	.48

DASS-Stress	1.04	0.60	0.71	0.38	5.28*	.54
DASS-Anxiety	0.44	0.51	0.30	0.29	3.01*	.31
Emotional and Cognitive Control						
WBSI	30.66	8.76	27.82	7.98	4.07*	.42
RRS-Brooding	9.18	2.82	8.14	2.13	4.27*	.44
RRS-Reflection	10.94	2.79	9.99	2.63	3.82*	.39
ERQ-Reappraisal	26.56	6.93	28.61	6.15	-3.51*	-.36
ERQ-Suppression	11.20	4.59	9.48	3.80	4.92*	.50
ACS	2.83	0.32	2.97	0.33	-4.49*	-.46

Notes: * = $p < .01$; Note: *SD* = standard deviation; *d* = Cohen's d effect size.
Description of the variables and their acronyms is shown in Table 1

Pre- and post-CCT network estimation

Figure 2 shows the regularized partial correlation networks before and after the CCT (see also Principal Components Analysis plot in Supplementary Figure 1). To complement interpretations based on visual inspection of the networks (Jones et al., 2018), we conducted correlational analyses to identify some relevant features of the networks.

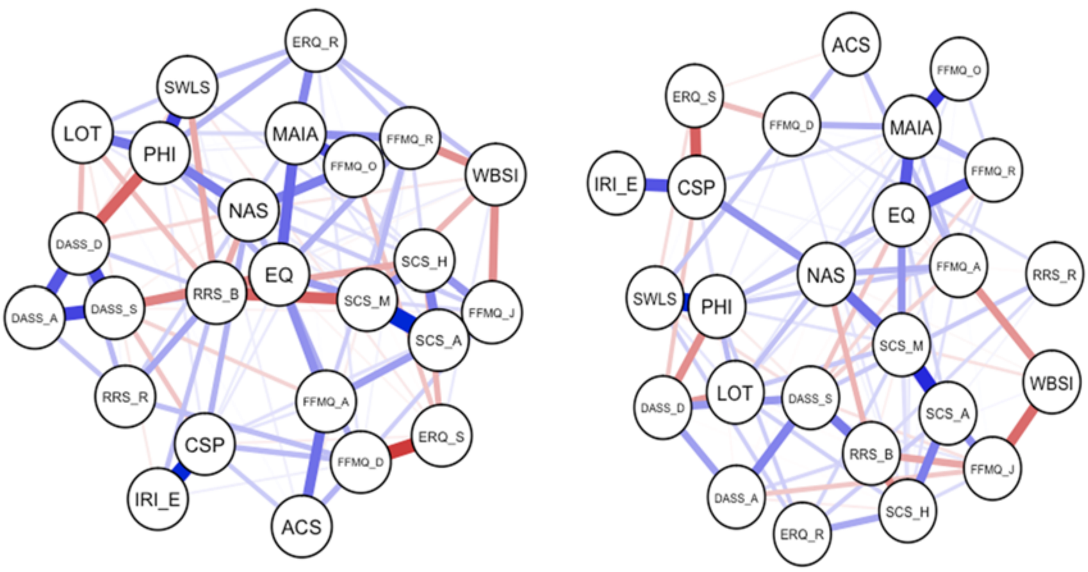
First, before the CCT, self-compassion measures (i.e., SCS) were negatively related to dysfunctional emotional and cognitive control measures (i.e., brooding [RRS-B], emotional suppression [ERQ-S] and thought suppression [WBSI]). Yet, after the program, SCS measures increased their strength of association with a number of adaptative emotional and cognitive control measures (i.e., emotional reappraisal [ERQ-R] and cognitive reflection [RRS-R]). Furthermore, these SCS measures became more strongly associated with the array of mindfulness measures (increasing the connections with decentering [EQ], non-attachment [NAS], acting with awareness [FFMQ-A], and non-judging [FFMQ-J]). Interestingly, self-compassion was strongly associated with the non-judgmental component of mindfulness (FFMQ-J), whereas it was largely disconnected from compassion to others and empathy measures (i.e., CSP and IRI-E), both before and after the CCT. In fact, compassion toward others (CSP) and empathic concern (IRI-E) formed a strong dyad both before and after the CCT.

Second, before the CCT, regarding emotion regulation measures, emotion reappraisal (ERQ-R), an adaptive emotion regulation strategy, was related to mindfulness (MAIA, FFMQ-R and FFMQ-D) and well-being measures (SWLS and PHI). However, after completing the program, reappraisal was related to self-compassion measures (SCS variables). Regarding emotional suppression (ERQ-S), a non-adaptive emotional regulation strategy, before the program it showed negative connections with describing and observing facets of mindfulness (FFMQ-D and FFMQ-O) and with common humanity (SCS-H). However, after the CCT, emotional suppression (ERQ-S) was strongly and negatively correlated with compassion toward others (CSP).

Third, regarding rumination measures, brooding (RRS-B) had the strongest negative edges (associations) in the network before the CCT: negative relations with non-attachment (NAS), well-being (SWLS and LOT), and self-compassion (SCS-H and SCS-M). Yet, most of these relations weakened after the program. The reflection component of rumination (RRS-R) was positively related to dysfunctional variables (e.g., depression, anxiety or brooding) before, but not after, the program.

Figure 2. Regularized partial correlation networks before (panel A) and after (panel B) the CCT. The networks are graphed by nodes (i.e., circles representing the psychological constructs described in Table 2) and edges (i.e., lines representing correlations between the different nodes). Blue edges represent positive correlations between nodes whereas red edges represent negative ones. The nodes spatial position within the networks is chosen by the Fruchterman-Reingold algorithm, placing close together those nodes with stronger and/or more connections while it places nodes with low centrality in the periphery. See list of nodes names in Table 2.

Pre-CCT (panel A) **Post-CCT (panel B)**



Pre- and post-CCT network inference

Overall, the constructs with the highest strength and expected influence (Robinaugh et al., 2016), both before and after the CCT, were several mindfulness measures (non-attachment [NAS], decentering [EQ], and interoceptive body awareness [MAIA]), compassion measures (self-compassion [SCS] and compassion toward others [CSP]), general well-being (PHI) and psychological distress (DASS) (Supplementary Figure 2). The Network Comparison Test (NCT; van Borkulo et al. 2017) examined whether the overall network connectivity significantly differed between pre- and post-CCT networks. The NCT showed no significant differences between pre- and post-CCT networks in the overall network structure (M = .25; p = .26), the global network strength (S = 1.20; p =.15) and the global network expected influence (S = 0.86; p =.33). However, there were pre-vs post-CCT statistically significant differences in the strength and expected influence of some specific edges and nodes. There was a significant strength reduction after the CCT in depression (DASS-D), the brooding component of rumination (RRS-B) and non-reactivity to inner experience (FFMQ-R), whereas there was there was a significant EI reduction of anxiety (DASS-A) and non-judgment (FFMQ-J). Reduction in global strength implies that activation of certain nodes (e.g., rumination) is less likely to co-occur with other nodes (e.g., depression) following the intervention. Furthermore, there was a significant EI increase of mindfulness self-compassion (SCS-M), whereas common humanity (SCS-H) was the node with the highest degree centrality increase after the CCT (i.e., SCS-H became highly interconnected to other nodes after the program). Finally, the nodes with the highest clustering increase after the CCT were emotional suppression (ERQ-S), thought suppression (WBSI) and anxiety (DASS-A), indicating that the neighbors of these nodes were more interconnected them after CCT.

Pre- and post-CCT nodes predictability

Figures 3 shows the pre-post-CCT predictability values for each node (i.e., how much variance of a node can be explained by other nodes in the network). The nodes with the highest predictability values before CCT were related to self-compassion (SCS-M = .84, SCS-A = .74, and SCS-H = .71), mindfulness (EQ = .79, NAS = .77, and MAIA = .70), general well-being (PHI = .83), and psychopathology-related constructs, such as depression (DASS-D = .83), anxiety (DASS-S = .74), and brooding (RRS-B = .81). Interestingly, while self-compassion, mindfulness and well-being predictability values remained stable after the program (see Supplementary Figure 3), the predictability of psychopathology-related constructs declined markedly after the CCT: depression (DASS-D; R^2_{pre}= .83, R^2_{post}= .56), anxiety (DASS-A; R^2_{pre}= .66, R^2_{post}= .41), stress (DASS-S; R^2_{pre}= .74, R^2_{post}= .61), brooding (RRS-B; R^2_{pre}= .81, R^2_{post}= .64) and emotional suppression (ERQ-S; R^2_{pre}= .44, R^2_{post}= .28). The pre- and post-CCT average predictability was quite similar (.61 and .57, respectively), and no significant differences were found between pre- and post-CCT predictability ($t_{(24)}$ = 2.29; p > .01). In other words, there was an overall average of 59% of the variance of a node predicted by all its neighbors. According to Haslbeck & Fried (2017), this signifies a high degree of predictability both before and after CCT.

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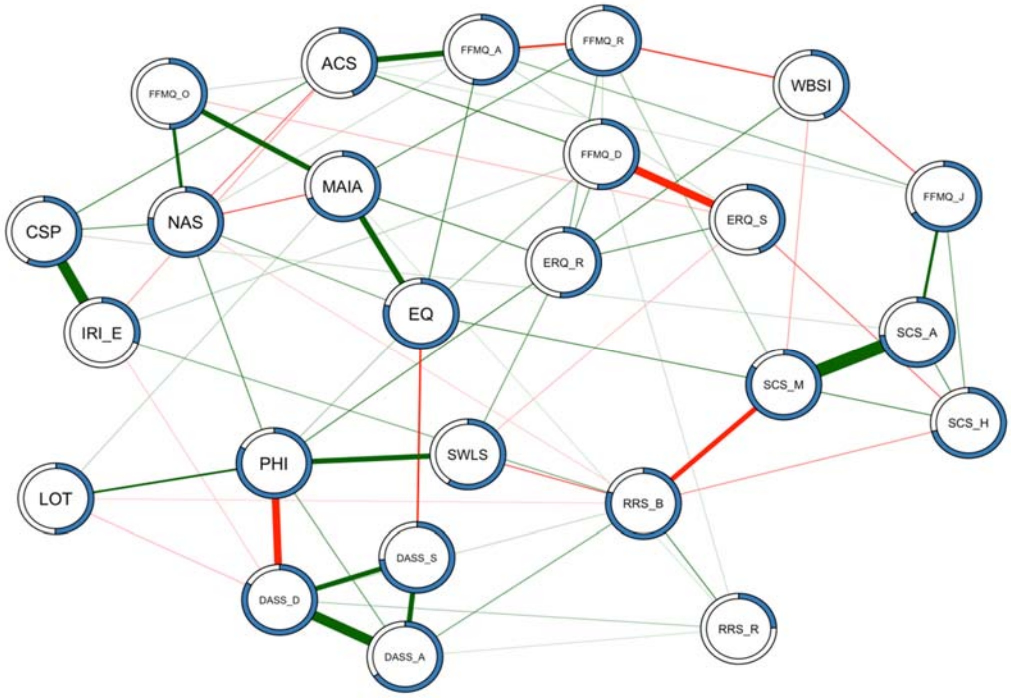
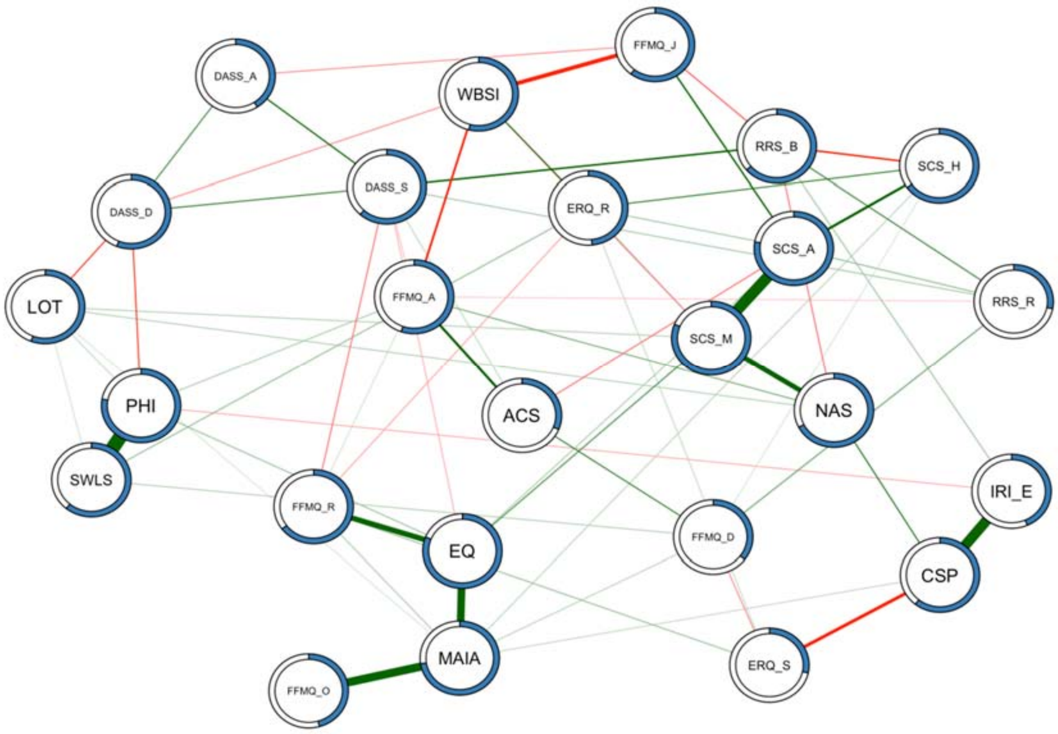
Figure 3. Nodes predictability before (panel A) and after CCT (panel B). The blue ring around each node represents the percentage of variance predicted by all its neighbors. Positive relations between nodes are represented with green edges and negative relations with red ones. See list of nodes names in Table 2.

Pre-CCT (panel A)



Post-CCT (panel B)

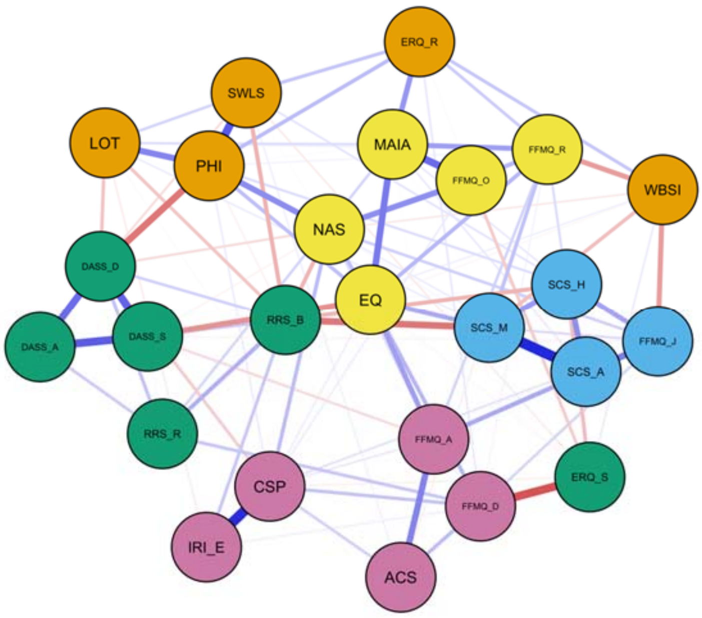


Pre- and post-CCT network node communities

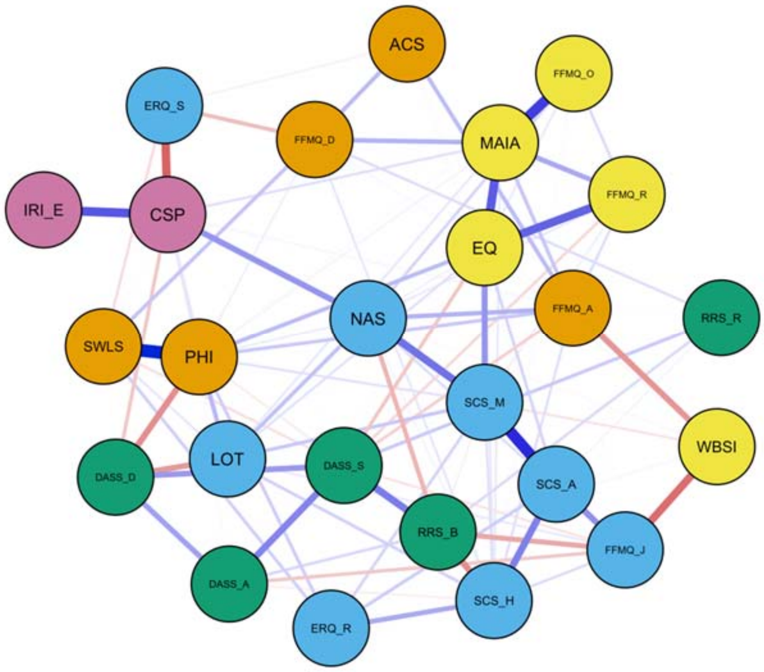
The spinglass algorithm detected five communities (i.e., cluster of nodes), both before and after CCT. Minor changes were observed in the communities' reorganization after the program (see Figure 4). Five communities remained largely unchanged after CCT: (1) The "psychopathological community" (cluster C, depicted in green) comprised the same nodes after the program (i.e., psychological distress and rumination), excepting emotional suppression (ERQ-S) that appeared with the mindfulness variables in cluster B; (2) The "self-compassion community" (cluster B depicted in blue) became the largest cluster after the CCT, now including nodes related to emotional regulation (ERQ-S and ERQ-R), non-attachment (NAS) and optimism (LOT); (3) The "mindfulness community" (cluster D, depicted in yellow) retained mostly the same nodes. However, several mindfulness nodes now appeared in different communities (clusters A, B, and D) after CCT; (4) Cluster A included well-being measures (general well-being [PHI] and life satisfaction [SWLS]) joined by attentional control (ACS), acting with awareness (FFMQ-A), and describing (FFMQ-D). Cluster E included only compassion toward others (CSP) and empathic concern (IRI-E).

Figure 4. Community detection analysis performed on pre (panel A) and post (panel B) CCT networks. The identified communities depict the variables that are more strongly inter-correlated. See list of nodes names in Table 2.

Communities in pre-CCT network (panel A)



Communities in post-CCT network (panel B)



Pre- and post-CCT bridge centrality

Estimates of one-step bridge expected influence are plotted in Supplementary Figure 4. Prior to the intervention, the three nodes scoring highest on this bridge centrality metric belonged to the emotional/cognitive control community (cognitive reflection [RRS-R = .38], emotional reappraisal [ERQ-R = .53] and attentional control [ACS = .41]), one to the mindfulness community (body awareness [MAIA = .39]) and one to the compassion community (compassion to others [CSP = .36]). Two self-compassion measures (self-kindness [SCS-A = .36], mindfulness self-compassion [SCS-M = .65]), two nodes from the mindfulness community (non-attachment [NAS = .45] and decentering [EQ = .35]), and emotional reappraisal (ERQ-R = .48) remained as high bridge nodes after the program. Interestingly, no psychological distress or psychopathological emotional/cognitive control measure appeared as a bridge node in the CCT networks.

Finally, we assessed the accuracy and stability of the networks (see further details in Supplementary Materials). Although estimated pre- and post-CCT networks appear reliable (see Supplementary Figure 5), the inferences drawn from centrality analyses should be interpreted cautiously due to the modest sample size and the low stability of the networks (see Supplementary Figure 6).

Discussion

The general aim of the study was to examine, by using network analysis, whether a standardized compassion program could change the structure of relations among different psychological constructs theoretically relevant for meditation and compassion practices. CCT yielded significant changes in almost all measures in the expected directions, replicating previous studies (Brito-Pons et al., 2018; Goldin & Jazaieri, 2017; Jazaieri et al., 2014). Furthermore, effect sizes indicated that the magnitude of these changes ranged from medium to large.

Using network analytic methods, we tested whether CCT would promote a favorable topological reorganization of the psychological constructs by which compassion variables become more connected with other variables measuring wellness and adaptive cognitive and emotional control. We found several notable changes in network topology following CCT. Changes in compassion-related measures were especially notable. Self-compassion measures were negatively related to dysfunctional emotional and cognitive control measures (e.g., rumination and emotional suppression) before CCT, but positively associated with adaptive variables (i.e., emotional reappraisal and cognitive reflection) after the program. Also, self-compassion was more strongly associated with mindfulness variables after CCT. These findings suggest that self-compassion plays a key role in adaptive emotional self-regulation (Neff, 2011). Emotion regulation often mediates the relation between self-compassion and positive mental health outcomes (Finlay-Jones, 2017; Inwood & Ferrari, 2018), and CCT enhances emotion-regulation processes (Jazaieri et al., 2014, 2018). Our finding that reappraisal becomes strongly associated with self-compassion after CCT suggests that increasing one's ability to be compassionate with oneself may enable people to reappraise situations in a less destructive way (Gilbert, 2019). On the other hand, non-adaptive suppression of emotions (Gross, 2001) became negatively associated with compassion for others after CCT. Hence, becoming aware of the suffering of others is associated with a diminished likelihood of suppressing one's own emotions. Brooding, a passive, judgmental evaluation of one's mood (Nolen-Hoeksema & Morrow, 1991), diminished after CCT. Its connections with other nodes diminished as well (i.e., non-attachment, well-being, and self-compassion). This finding makes sense as brooding seems incompatible with the motivation to alleviate suffering characteristic of compassion (Strauss et al., 2016).

We found nodes signifying compassion, mindfulness, and well-being were especially central both before and after CCT. Expected influence and strength centrality indices were highest for compassion (self-compassion and compassion toward others) and mindfulness variables (non-attachment, decentering and interoceptive body awareness) both before and after CCT. Furthermore, self-compassion, non-attachment and decentering were the highest bridges nodes (i.e., the nodes most likely to activate nearby communities of nodes). These bridge nodes would act as "modulators" of the different sub-networks (i.e., communities). For instance, in the case of psychological distress (i.e., DASS nodes) and rumination (i.e., RRS-Brooding), non-attachment and self-compassion served this purpose, decoupling psychopathological variables from the rest of the network. Something similar happens in brain dynamics, where some networks serve as inhibitors of others (Menon, 2011). Therefore, bridge centrality is especially meaningful to interpret the CCT-induced changes because the function of bridge nodes is to distribute the information through the network, acting as mechanisms to couple sub-networks of adaptive variables (e.g., self-compassion, mindfulness, well-being, etc.), while decoupling sub-networks of non-adaptive variables (e.g., psychological distress, rumination, emotional suppression, etc.). Future studies should test these adaptive and non-adaptive sub-networks separately in order to (1) analyze the structure of each sub-network, under the hypothesis that psychological interventions should couple adaptive sub-networks while decoupling non-adaptive ones; and (2) calculate the predictability in each sub-network instead of global predictability. If there is an increase of predictability after the program in the adaptive sub-networks and a decrease in the non-adaptive ones, then the intervention has enhanced the consolidation of overall positive states which, in turn, would act as "protective dynamic sub-networks" inhibiting the influence of other non-adaptive sub-networks once they are activated. A similar protective function has been found in animal ecosystems and even in bacterial networks (Castellanos et al., 2020).

Our results are compatible with previous findings showing that compassion programs target both compassion and mindfulness skills (Brito-Pons et al., 2018; Jazaieri et al., 2014; Kirby et al., 2017) by using mainly explicit or implicit strategies, respectively (Brito-Pons et al., 2018). Furthermore, most compassion meditation exercises include mindfulness skills in the learning process, which is the focus of the first module of CCT (Goldin & Jazaieri, 2017). Within mindfulness skills, non-attachment had a central role in CCT networks. Non-attachment is defined as the absence of fixation on thoughts, emotions or sensory objects, as well as an absence of internal pressure to change, approach or avoid these experiences (Sahdra et al., 2010). Our results are in line with those showing that non-attachment is one of the main mechanisms of action in meditation-based programs (Hölzel et al., 2011; Tanay et al., 2012), expanding this finding to compassion programs. Thus, non-attachment would promote a change in the perspective on the self that is crucial for understanding the effects of meditation (Gunaratana, 2009).

On the other hand, although there were no significant changes in the global network structure, there was a significant reorganization of the edges and nodes contributing to network strength and expected influence, which was consistent with our third hypothesis. The nodes with the highest expected influence and strength reduction after CCT were depression, anxiety, brooding, non-judgment and non-reactivity to inner experience, whereas self-compassion measures exhibited the greatest increase in centrality after CCT. Although these changes may partly be attributable to regression toward the mean, they are also in accord with previous findings (Kirby et al., 2017; Neff, 2003b). The results not only indicate reductions in depression, anxiety, and rumination average scores after CCT, but also that their centrality diminished as well. Whereas mindfulness programs are primarily a cognitive practice in which 'bare attention' (i.e., the ability to notice sensations, thoughts and emotions) is cultivated (Wallace & Shapiro, 2006), compassion programs are rather emotion-focused as participants are trained to be aware of ones and others' suffering (Jinpa, 2010).

A previous research has found that mindfulness and well-being became the most central nodes after participants had undergone a Mindfulness-Based Stress Reduction (MBSR) program, whereas attentional control, depression, thought suppression, and several compassion measures were the nodes with the highest centrality changes after the program (Roca et al., 2019). Taken together, these results and the present ones suggest that there are common and specific mechanisms of change in MBSR and CCT. Whereas in both programs, mindfulness variables are among the most central nodes in their respective networks, well-being variables are more central in the MBSR network and compassion variables are more central in the CCT network. Also, whereas some of the nodes with the highest centrality change after the program seem to be similar in both programs (i.e., depression and some non-adaptive cognitive control measure such as brooding or thought suppression), other changes seem specific to each program, (e.g., the centrality changes in attentional control only appear after the MBSR program).

Although compassion toward others was largely disconnected from self-compassion, it was a highly central node, strongly connected with empathic concern, non-attachment, and negatively correlated with emotional suppression. In this study we used the Compassion Scale (Pommier et al., 2019) as a measure of compassion for others. The operationalization of this scale was similar to Neff's (2003a) self-compassion model, measuring compassion for other’s suffering in terms of attention (i.e., mindfulness), cognitive understanding (i.e., common humanity), and emotional responding (i.e., kindness). Surprisingly, although both scales come from the same theoretical model, the correlation between self-compassion and compassion toward others is usually small to medium (Pommier et al., 2019). Given that the general factor in the Compassion Scale account for a substantial amount of variance in the response (Pommier et al., 2019) we decided to use the total score in the networks. However, it is likely that the separate components of the scale may have different connections with other variables within the network. Furthermore, despite the importance of being aware of others’ suffering, futures studies should include measures of the “action” component of compassion (i.e., behaviors intended to alleviate the suffering of others), such as the Compassionate Engagement and Action Scales (Gilbert et al., 2017) or observations of actual compassionate behaviors. Future studies should also examine the discrepancies between self- and other-compassion as a potential mechanism of the CCT program (e.g., do participants with greater self-other compassion discrepancies behave differently than those with low compassion discrepancies?).

Consistent with our fourth hypothesis, compassion, mindfulness, and well-being were the most predictable nodes (i.e., variance explained by other nodes in the network), both before and after CCT. Also, psychopathology-related constructs (i.e., depression, anxiety, stress, brooding, and emotional suppression) exhibited reductions in predictability after the program, suggesting that psychological distress and psychopathology-related measures became less connected to other variables following CCT. Interestingly, these psychopathological nodes not only decreased their predictability after the program, but also became less interconnected to each other. In other words, these symptoms tend to “decouple” when individuals improve their mental health. For instance, when a person is stressed out, an increase in stress and anxiety would lead to an increase in depression and rumination, whereas when the person learns how to regulate his or her emotions and thoughts after practicing compassion, an increase in stress and anxiety would not lead to an increase in depression and rumination. The opposite is also true for the well-being nodes: before the CCT program well-being variables were decoupled in the network (i.e., less predictable), whereas after the program well-being variables became more coupled by increasing their correlations with the variables trained in the program (i.e., compassion and mindfulness skills).

Inconsistent with our fifth hypothesis, community detection analyses revealed that the five clusters of nodes detected before CCT (i.e., psychopathology, self-compassion, mindfulness, well-being and compassion) remained largely intact following the program. This result contrasts with our previous study that showed a community reorganization among nodes following MBSR in accordance with theoretical expectation (Roca et al., 2019). Interestingly, the pre-CCT communities in the present study were very similar to those of the post-MBSR communities in Roca et al.'s (2019) study a finding potentially attributable to differences in the percentage of participants with previous meditation experience in our CCT participants (85.4%) than in Roca's MBSR group (56.0%). The difference is unsurprising because mindfulness skills are typically taught before compassion skills in meditation programs (Dahl & Davidson, 2019) and, for many participants, compassion training commences only after one has undergone mindfulness training.

Network analysis is a relatively novel way to elucidate mechanisms of change in compassion programs, extending the potential use of the 'psychonectome' perspective (Roca et al., 2019) to other meditation practices as well as other interventions aimed at promoting well-being (Blanco et al., 2020). Although latent variable and network models are ontologically distinct (McNally, 2020), they are statistically fungible (van Bork et al., in press). Accordingly, we drew on both approaches in the present study. Furthermore, our study combines state-of-the-art network analysis procedures (including a sequential network analysis procedure based on six steps), together with novel centrality metrics (i.e., expected influence, bridge centrality), plus a robust set of measures tapping key components of compassion.

Limitations and Future Research Directions

Our study has limitations. The number of participants per node was modest. Moreover, although our networks were reasonably reliable, the stability of the centrality estimates was low. Also, most participants had previous meditation experience from different traditions. Although this might have influenced our results, few individuals enrolling in compassion programs lack prior meditation experience. Another limitation of the study was that only post-intervention changes were analyzed. Although still infrequent in the meditation literature, future studies should include longitudinal designs to facilitate inferences on directionality and causality of the networks (Borsboom & Cramer, 2013; Gao et al., 2017). Given that multiple constructs were measured with common methods (i.e., multiple-item scales presented within the same survey), there might be spurious correlations among the constructs, also known as Common Method Biases (Podsakoff et al., 2003). Although we used partial correlations to compute our networks (i.e., a statistical remedy to minimize these problems), future studies might overcome these limitations by obtaining measures from different sources, including behavioral or psychophysiological indicators (e.g., Kim, Parker, et al., 2020). A more comprehensive mechanistic approach of MBIs could be achieved in integrating these types of variables in network analysis as some authors have begun to do (e.g., Heeren & McNally, 2016). Future analyses should include attentional performance as one of the nodes of the networks (Roca & Vazquez, 2020). Finally, it is also important to interpret the present results with caution as network analysis methods are still under development in psychology. The robustness of these results would be supported if future research replicates them with other meditation types (e.g., deconstructive practices), meditation experience (e.g., novices vs experts), clinical populations (e.g., mood disorders), and practice settings (e.g., meditation retreats).

In sum, our study contributes to research on compassion. Network analysis provides a novel perspective on changes induced by compassion training, such as CCT that implicate specific mechanisms of change. Our study shows that, after CCT, the map of variables is reorganized such that compassion becomes more connected with measures related to well-being and adaptive functioning. Also, compassion treatment seems to reduce the role that negative repetitive thoughts (i.e., brooding), may have in the entire network. This finding suggests that compassion may figure as an ingredient of therapies aimed at reducing emotional disorders by targeting rumination (e.g., Watkins, 2015).

Finally, high gains of compassion in network centrality seems to validate that CCT is truly operating by directly increasing the purposed mechanism of compassion whereas, by comparison, MBSR trainings seem to increase the centrality of attentional variables (Roca et al., 2019). In sum, network analysis illuminates the distinctive pathways through which different MBIs seem to operate. We hope that our study encourages researchers to undertake research including variables, other than those of self-report, to deepen our understating of why and how meditation interventions work.

Conflicts of interest: The authors declare that they have no conflict of interest.

Compliance with Ethical Standards: Participants provided informed consent prior to their inclusion in the study. Furthermore, the study was approved by the Complutense University ethics committee prior to participant recruitment and was registered at ClinicalTrial.org (NCT03920241).

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Author Contributions: PR and CV developed the study conception and design. Testing and data collection were performed by PR and GD. Data analysis and interpretation was performed by GD and PR. The first draft of the manuscript was written by PR, under the close supervision of CV and RM. PR, CV, and RM drafted the manuscript. All the authors approved the final version of the manuscript for submission.

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DISCUSSION AND CONCLUSIONS

CHAPTER 11

GENERAL DISCUSSION

The main goal of the present dissertation was to examine the effects and mechanisms of change in standardized mindfulness and compassion programs. Growing empirical evidence suggests that MBPs enhances well-being and reduces psychopathology (Goldberg et al., 2018; Hedman-Lagerlöf et al., 2018). However, less is known about the mechanisms of change explaining these effects, and we still do not know exactly *how* and *why* meditation works. Over the last decades, several theoretical models have explored the potential mechanisms of change and processes underlying the benefits of MBPs, but further empirical studies are needed. Furthermore, the scope of scientific research has focused almost exclusively on mindfulness meditation. Other forms of meditation have not received the scientific attention they deserve (Davidson & Dahl, 2018; Van Dam et al., 2018), as is the case of compassion meditation (Goetz et al., 2010; Strauss et al., 2016). Interestingly, some studies suggest that mindfulness and compassion meditation may yield different psychological effects and mechanisms (Brito-Pons et al., 2018; Fox et al., 2016; Singer & Engert, 2019).

The four studies presented in this doctoral dissertation aim to contribute to a deeper understanding of the effects and mechanisms in mindfulness and compassion programs. Through designing a comprehensive procedure combining different assessment methods and diverse assessment moments, we have tried to overcome some of the main limitations in this field (Davidson & Kaszniak, 2015; Goldberg et al., 2018; Rosenkranz et al., 2019; Van Dam et al., 2018).

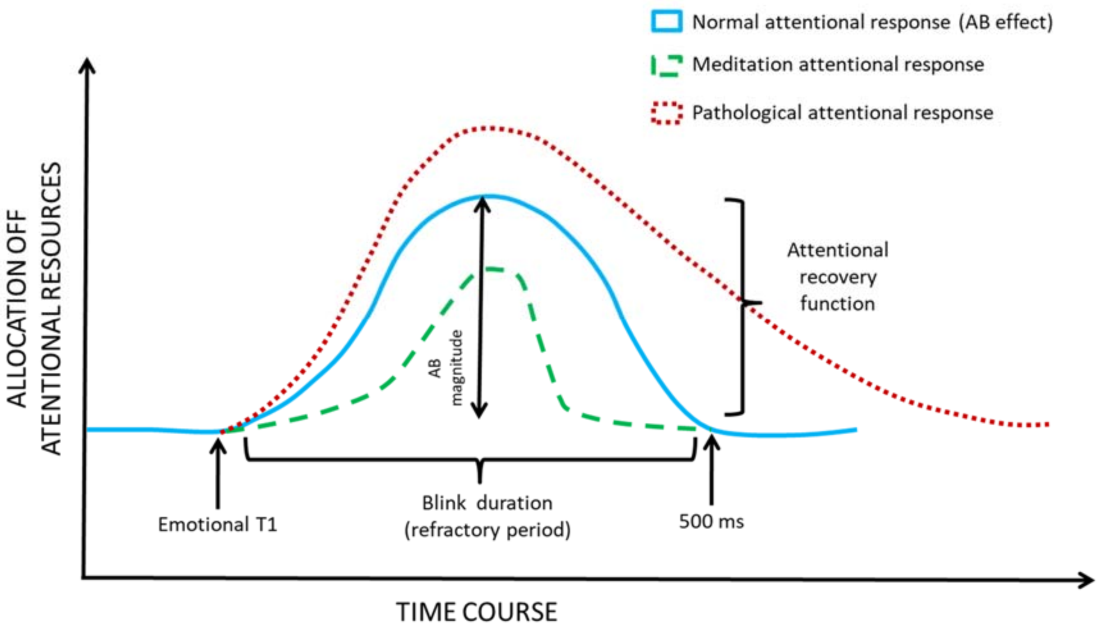
First, in Chapters 1 and 2, we provided a general overview of the effects and mechanisms of the MBPs. We emphasized the central role of attention, in general, and attentional processing of emotional information, in particular. In Chapter 3, we described some of the most widely used meditation taxonomies, as well as differences between compassion and mindfulness meditation. In Chapter 4 and 5, we introduced the readers into two key methodological tools of this dissertation: 1) The Attentional Blink paradigm as a way to study how meditation practice changes early stages of attentional processing of emotional information (Chapter 4); and 2) the use of network analysis as an alternative statistical approach to study the relationship between outcomes and mechanisms of change in MBPs (Chapter 5). In Chapter 6, we described our experimental procedure, participants, the mindfulness and compassion programs, and the measures administered across different phases of the interventions.

Chapters 7 to 10 consisted of the four empirical articles conforming this doctoral dissertation. In Chapter 7, we presented our adaptation of the classical Attentional Blink task using negative, positive and neutral stimuli, and its potential use as a measure of attentional changes towards emotional information promoted by structured meditation trainings. In Chapter 8, we included our study examining the relative effectiveness and mediators of change in mindfulness and compassion standardized programs, assessed via traditional univariate statistics and mediation analysis. Finally, Chapters 9 and 10 included two articles employing network analysis to explore the changes in the relationships between psychological variables after the mindfulness (Chapter 9) and compassion programs (Chapter 10). In the next sections, we will discuss the major findings from the studies mentioned above (Chapter 11), as well as potential clinical implications (Chapter 12), limitations and future directions (Chapter 13), and final conclusions (Chapter 14).

11.1 DOES MEDITATION CHANGE THE PROCESSING OF EMOTIONAL INFORMATION?

Our first aim was to examine whether mindfulness and compassion meditation modulate the attentional processing of emotional information. With this goal in mind, we developed a variation of the Attentional Blink paradigm using negative, positive and neutral stimuli. In our article presented in Chapter 7, we found that both mindfulness and compassion programs reduced the AB deficit, extending previous findings to brief 8-week meditation trainings (Slagter et al., 2007; van Leeuwen et al., 2009). This suggests that meditation practice may improve early automatic stages of emotional processing by increasing the flexibility of resources allocation (Malinowski, 2013; Moore et al., 2012). Specifically, meditation practice might reduce the attention captured by the emotion depicted in the first target, promoting a faster disengagement from the emotional stimulus and reorientation to the second target. In other words, both meditation programs seem to change the time course of attentional processing of emotional stimuli. Inspired by Davidson’s model of physiological response to emotional stimuli (Davidson, 2003; Davidson & Begley, 2013) and Desbordes et al.'s (2015) model of temporal domain of equanimity, we propose a model in which some of its parameters could guide how meditation practices change the attentional response to emotional stimuli, as measured by the Attentional Blink paradigm (see Figure 10).

Figure 10. Theoretical model representing how meditation practice may change attentional responses to emotional stimuli. Compared to a normal AB effect (i.e., blue line), meditation training may reduce attentional resources captured by the emotional T1 while enhancing recovery of attentional resources (i.e., dashed green line – fast attentional disengagement and reorientation). A pathological attentional response (i.e., red dotted line), as in emotional disorders (e.g., anxiety or depression), would be characterized by a larger magnitude of AB accompanied by more resources captured by T1 and a slower recovery of attentional resources.



Interestingly, we also found that this post-intervention AB reduction varied depending on the valence of emotions presented. Both meditation programs led to more accurate detection of angry faces in the shortest time lag, happy faces in short and medium time lags, and neutral faces in all three time lags (i.e., short, medium and large). A plausible explanation of our results is that meditation practice helps balance out our 'negativity bias' by promoting the processing of positive and neutral stimuli, thereby promoting a less biased attention for any stimuli. Thus, these results highlight the potential effects of meditation practice for the modification of attentional biases (Conklin et al., 2019; Davis & Thompson, 2015; Ford & Shook, 2019; Garland et al., 2015a; Kiken & Shook, 2012; Roberts-Wolfe et al., 2012; Vago & Nakamura, 2011). Meditation may reduce the attentional bias to negative stimuli by broadening the attentional field (e.g., strengthening attentional disengagement and reorientation), and enabling detection of neutral and positive stimuli that might have been previously ignored (Davis & Thompson, 2015; Garland et al., 2015a). Thus, meditation training is postulated as a feasible and effective alternative over traditional Attentional Bias Modification procedures, which have shown very limited effectiveness in modifying attentional biases (Cristea et al., 2015).

Attentional biases in both healthy participants and individuals with emotional disorders may arise from engagement-disengagement difficulties when processing emotional information (Armstrong & Olatunji, 2012). The results of our study showed that meditation programs improve the disengagement of attentional resources from the first target and free up attentional resources that are now available for the processing of positive and neutral information. This change could be interpreted as an overall improvement in adaptive emotion regulation strategies (Garland et al., 2015a; Roberts-Wolfe et al., 2012; Vago & Nakamura, 2011). However, both programs similarly reduced the AB deficit, and only marginal differences emerged in the processing of emotional information. Future studies should include a third group (e.g., a wait-list control group without any meditation training) and seek to replicate these results. This would help to (1) determine if observed improvements are due to practice effects and (2) reveal more subtle differences between mindfulness and compassion practices. Research employing a fully randomized design is also needed to minimize the potential influence of self-selection bias. Lastly, future studies should seek to include clinical samples with high baseline levels of distress and attentional biases.

11.1.1 AB Task as an Indicator of Equanimity

Based on theoretical models rooted in Buddhist tradition, it would be reasonable to hypothesize that improvements in the balance of emotional information processing might indicate enhanced equanimity toward unpleasant, pleasant, and neutral feeling tones (Batchelor, 2019; Nhat Hanh, 1999). Equanimity can be defined as an even-minded mental state towards all experiences, regardless of their hedonic tone (Desbordes et al., 2015; Hadash et al., 2016). Meditators learn to be mindful of feeling tones arising from the present-moment experiences (i.e., fewer attentional biases) and work toward an accepting, non-judgmental attitude toward those experiences, thereby reducing emotional and cognitive reactivity (Batchelor, 2019; Shapiro et al., 2006). Thus, equanimity could be understood as an emotional regulation strategy, promoting a faster recovering from emotional information (Desbordes et al., 2015). In our version of the AB task, equanimity would be operationalized as a faster disengagement from emotional information after the programs and a more balanced distribution of attentional resources toward emotional information, improving the processing of neutral and positive stimuli. Although neutral stimuli may be qualified as 'boring' or emotionally inert, from a meditative perspective, neutral feeling tones are a source of restful and peaceful states, and practitioners are guided to learn how to transform 'boredom' into a 'quiet contentment'. Awareness of pleasant feeling tones is also important, as it helps us to recalibrate the effect of unpleasant feeling tones and achieve a neutral baseline (Batchelor, 2019). Considering the methodological limitations of self-report measures to quantify equanimity (Desbordes et al., 2015), future studies should explore the potential use and validity of this emotional variant of the AB task as an indirect measure of equanimity.

11.1.2 AB Task as an Awareness Measure

Furthermore, as mentioned in Chapter 4, the AB deficit could be interpreted as a deficit in the access of information to awareness. The classical AB deficit illustrates the temporal cost of encoding a stimulus into working memory (Olivers & Meeter, 2008), acting as an index of the attentional limits of conscious perception (Dux & Marois, 2009). Therefore, our variant of the AB task could be used to measure how emotional stimuli reach the level of conscious perception, rendering the AB an ideal paradigm for investigating the effects of meditation practice. Although attention and conscious perception are different processes, whilst related phenomena, literature on cognitive processes in meditation has focused on the attentional effects of meditation rather than on its effects on conscious perception (Schofield et al., 2015). Our results are consistent with the hypothesis that meditation facilitates greater awareness of one's sensory and perceptual experience (Lutz et al., 2008), by increasing the conscious identification of very rapidly presented emotional stimuli. According to our findings, the simplified view of meditation as a tool to merely improve attention may not do justice to the nuances of its effects on other processes, such as the conscious identification of emotional information. Future research should explore the extent to which automatic attentional changes towards emotional stimuli (as revealed in our AB task) interact with conscious strategies to redirect attention (Saunders et al., 2016).

11.1.3 COGNITION AND EMOTION IN MEDITATION

The interaction between cognitive and emotional processes involved in meditation was also observed in our other studies. In Chapters 8 to 10, using self-report measures, we found significant improvements in cognitive and emotional regulation-related measures, such as cognitive reappraisal, acceptance, and attentional control, as well as reductions in emotional suppression, rumination, and though suppression. For instance, in Chapter 8 we found that changes in decentering, a meta-cognitive ability to observe the mental activity without being attach to the emotional content, was a crucial mechanism to explain the benefits of MBPs on psychological distress (i.e., stress, anxiety and depression) and well-being. In Chapter 9 and 10, by using network analysis with self-report measures, we found that some non-adaptive emotional regulation measures, such as brooding or thought suppression, were the nodes with the highest centrality changes after both mindfulness and compassion programs, whereas other changes were specific to each program (e.g., attentional control in MBSR or self-compassion in CCT).

An important clinical implication derived from these results is the potential mediating role of changes in attention on changes in psychological distress and well-being. As mentioned in Chapter 2, cognitive theories suggest that cognitive and attentional biases are key transdiagnostic factors for understanding the etiology and maintenance of different psychopathologies, such as mood disorders, substance abuse, or pain distress, among others (Field & Cox, 2008; Gaffiero et al., 2019; Van Bockstaele et al., 2014). In Chapters 8 to 10, we found that both mindfulness and compassion programs significantly reduced psychological distress (i.e., stress, anxiety and depression), certain psychopathological variables (e.g., rumination, thought and emotional suppression), and psychological well-being. It could be hypothesized that these positive effects of the MBPs could be mediated, at least partially, by improvements in these cognitive and attentional biases (De Raedt et al., 2012; Kiken & Shook, 2011; Roberts-Wolfe et al., 2012), which we are currently analyzing. Thus, MBPs are postulated as effective tools improve mental health by modifying cognitive and attentional biases patterns.

11.2 DOES MEDITATION TYPE MATTERS?

After analyzing the cognitive effects of mindfulness and compassion meditation (i.e., attentional processing of emotional stimuli), our second aim was to examine the effectiveness, psychological effects, and mechanisms of change in standardized mindfulness and compassion meditation programs (see Chapter 8). As shown in Chapter 7, we found that mindfulness and compassion programs yielded similar reductions in the attentional processing of emotional information, and only marginal differences emerged between them. The question now would be: Do the two programs produce the same self-reported psychological changes? Do they operate through the same mechanisms of change?

11.2.1 COMMON AND SPECIFIC EFFECTS IN MEDITATION PROGRAMS

Firstly, the results from Chapter 8 showed that both programs significantly increased self-reported levels of mindfulness, decentering, body awareness and self-compassion. Yet, increases in present-moment awareness (i.e., trait mindfulness, decentering and body awareness) were significantly larger in MBSR, whereas socio-emotional changes (i.e., common humanity and empathic concern) were larger in CCT. It is noteworthy that the magnitude of these differences had medium to large effect sizes since these interventions were relatively brief (Rubio-Aparicio et al., 2018; Schäfer & Schwarz, 2019). Our results are broadly consistent with previous work (Brito-Pons et al., 2018; Singer & Engert, 2019), extending previous findings to the study of the mechanisms of change of these two particular programs. Taken together, these findings suggest that there are both shared and specific effects in mindfulness and compassion standardized programs. Although both programs showed an overall positive effect on the psychological variables studied, the magnitude of these changes differed depending on the program.

A plausible explanation for these results could be the overlap in the program content. Certainly, mindfulness is a fundamental keystone for other meditation practices (Dahl & Davidson, 2019); in fact, it is formally practiced at the beginning of compassion programs. And these influences are bidirectional. Self-compassion and kindness are transdiagnostic elements implicitly taught in mindfulness programs (Neff & Dahm, 2015). Future research should explore whether mindfulness practices may facilitate other meditative practices, such as compassion meditation, and whether compassion elements are crucial in mindfulness programs (Dahl & Davidson, 2019). Our experimental design, as it stands, does not allow us to test this hypothesis. Future research may also seek to compare the effects of modular mindfulness and compassion trainings, as well as dismantling and additive component studies (Bell et al., 2013) (see more details in 'Chapter 13: Clinical implications').

To further test the efficacy of the interventions, we used the Reliable Change Index (RCI). The RCI revealed no differences between MBSR and CCT in terms of clinically significant changes in stress, depression, and well-being. However, the MBSR program had significantly fewer participants with no changes in anxiety levels than did the CCT program. Three general conclusions can be drawn from the RCI: 1) All the outcomes showed a large proportion of beneficial changes (i.e., recovered plus improved, more than 50% of the cases); 2) The outcomes with the largest proportion of beneficial changes were stress reduction and well-being improvement; and 3) only a tiny fraction of participants showed any deterioration from baseline, which is an important result considering the potential adverse effects of psychological interventions (e.g., Ebert et al., 2016; Rozental et al., 2017), including meditation practice (Cebolla et al., 2017; Lindahl et al., 2017; Van Dam et al., 2018).

11.2.2 MECHANISMS OF CHANGE OF PSYCHOLOGICAL DISTRESS AND WELL-BEING

Secondly, we found that both mindfulness and compassion programs were equally effective in reducing psychological distress (i.e., stress, anxiety, and depression) and promoting well-being. However, the mechanisms of change through which mindfulness and compassion meditation achieved these outcomes differed. While the mindfulness program mainly operates through changing present-moment awareness variables (such as decentering and body awareness), the compassion program fosters the same positive outcomes through changes in socio-emotional variables (such as common humanity and empathy). These results may have clinical implications to improve the efficacy of MBPs and develop personalized interventions. For instance, if an individual wants to reduce stress and enhance well-being, but her main problem is that she does not know how to control her mental activity and rumination, the MBSR might be the best option, as it boosts decentering skills. Another individual with exactly the same goals (i.e., to reduce stress and increase well-being) who battles high levels of self-criticism and a sense of isolation might benefit more from a CCT program, which facilitates improvements in common humanity. One fertile area for future research is to examine the baseline predictors of the efficacy of MBPs, following the personalized medicine framework (see section '12.4 Clinical implications' for more information).

11.2.3 THE ROLE OF DECENTERING

Our results also revealed decentering as the most important mechanism to distinguish the effects of mindfulness and compassion programs on psychological distress and well-being. This finding replicates previous studies in the field (Bhambhani & Cabral, 2016; Gecht et al., 2014). Of the multiple mediations tested, we found that decentering was the only mediator still showing a significant indirect effect after controlling for baseline covariates and other mediators. Moreover, in Chapters 9 and 10 it is described that decentering was a high central node in both MBSR and CCT. As mentioned in Chapter 2, decentering can be defined as a meta-cognitive ability to observe the objects that arise in the mind (i.e., perceptions, thoughts, feelings, or memories) with a healthy psychological distance (i.e., observing the thoughts without being attached to them). It is similar to the concept of "cognitive defusion", a technique used in Acceptance and Commitment Therapy. Clarifying the key role of decentering as a crucial mechanism in meditation programs will promote the inclusion of 'decentering practices' in broader psychological treatment protocols (Brown et al., 2007; Craig et al., 2008). Future studies should design 'decentering inductions' in clinical settings, as well as 'experimental decentering trainings', following the model of the Cognitive Bias Modification interventions (Jones & Sharpe, 2017).

11.2.4 REQUIREMENTS FOR DEFINING THE MECHANISMS OF CHANGE

As mentioned in Chapter 2, our study met Kazdin's (2007, 2009) requirements for demonstrating genuine mechanisms of change: 1) All our mediation models showed strong associations between the MBPs, the mediator of change and the outcomes (even after controlling for the covariates). These associations explain a substantial percentage (50-60%) of variance in symptom reduction and well-being improvement resulting from the intervention; 2) Our results also demonstrated the specificity of the effects; from the many psychological constructs tested as plausible meditators, only few specific changes mediated each program, especially in the case of decentering; 3) Despite the novelty of our research, the results converge with those of previous studies (Brito-Pons et al., 2018; Gecht et al., 2014; Singer & Engert, 2019). Nevertheless, future studies are needed to replicate these mechanisms in different samples and conditions; 4) According to out ANOVAs, the experimental manipulations across the 8-week mindfulness and compassion programs effectively and significantly altered the proposed mediators of change; 5) Importantly, our mediation models were conducted on changes scores (post-intervention score – pre-intervention score), as the outcomes and mediators were assessed at multiple time points; 6) Our study design will allow us to test the gradient hypothesis and analyze whether higher doses of the intervention (e.g., higher meditation home practice in the inter-session assessment) are associated with greater activation of the mediators; and 7) finally, we selected all our mediators and outcomes based on psychological theories of mindfulness (Goldberg et al., 2018; Gu et al., 2015; Hölzel et al., 2011; Malinowski, 2013; Wielgosz et al., 2019) and compassion meditation (Goetz et al., 2010; Goldin & Jazaieri, 2017; Kirby et al., 2017; Strauss et al., 2016), so that our results are coherent and plausible.

11.2.5 INCLUSION OF WELL-BEING MEASURES

A major strength of this study was the inclusion of well-being as a main outcome in our analyses. Traditionally, studies analyzing the efficacy and mechanisms of change in psychological interventions focus exclusively on negative affect and psychopathological outcomes, while ‘positive variables’ are usually ignored (Schotanus-Dijkstra et al., 2019). Meditation training differs from most psychotherapies in that it is sought not only for relief of unnecessary suffering, but also to promote well-being, life satisfaction and human flourishing. However, as Davidson & Dahl (2018) observed, well-being has scarcely received attention in mindfulness research, despite being one of the most important targets in contemplative practices (see Chapter 1). The present doctoral dissertation aimed to address the question of whether MBPs enhance well-being even in those who are already doing generally well (i.e., community sample) by including positive outcomes in our protocol.

11.3 DO MINDFULNESS AND COMPASSION CHANGE THE MIND?

Finally, the third aim of the dissertation was to examine structural changes in the relationships between psychological variables in mindfulness (Chapter 9) and compassion programs (Chapter 10) via network analysis. In Chapter 8, we described the use of mediation analysis to analyze the mechanisms of change in the MBPs. These traditional mediation analyses (Hayes, 2009) typically include only few variables in the model and, furthermore, assume that the expected changes resulting from interventions are linear and unidirectional. However, several theoretical models have systematized the mechanisms of change underlying MBPs and revealed complex matrices of bi-directional relationships between a large number of outcomes and mechanisms which change in dynamic ways over the intervention course (see Chapter 2). These complex interactions between psychological, cognitive and biological processes may help explain the lack of consensus on the mechanisms underlying MBPs (Wielgosz et al., 2019). An alternative approach to study the complex matrix of outcomes and mechanisms of change is network analysis (see Chapter 5). In network analysis, the focus is transferred from the changes in individual variables (Chapter 8) to the changes in the relations between them (Chapter 9 and 10), which could shed light on structural changes after the MBPs.

To contrast the traditional approach with the innovative network approach, we used classic univariate statistics to compare pre-post scores in mindfulness (Chapter 9) and compassion (Chapter 10). Our results converged with those of previous studies: Levels of mindfulness, compassion, well-being and adaptive cognitive-emotional regulation measures (such as cognitive reappraisal or attentional control) significantly increased, while levels of stress, anxiety, depression, and dysfunctional cognitive-emotional regulation measures (such as emotional suppression, rumination or thought suppression) significantly decreased (Goldberg et al., 2018; Gu et al., 2015; Kirby et al., 2017; Leaviss & Uttley, 2015; Wielgosz et al., 2019). Yet, this analytic approach does not enable us to investigate mechanistic changes in the relationships between psychological variables relevant to mindfulness and compassion practice.

11.3.1 NETWORK FEATURES

The mindfulness and compassion networks we modelled displayed several interesting features. First, in the MBSR networks, self-compassion variables established strong connections with well-being and mindfulness measures after the intervention. This converges with earlier evidence of links between self-compassion and greater psychological well-being (Zessin et al., 2015) and mindfulness (Raab, 2014) emerging from participation in MBSR programs. In the CCT networks, self-compassion measures were related to emotional and cognitive regulation measures, reducing their relations with dysfunctional regulation measures (e.g., brooding, emotional and thought suppression) and increasing their strength of associations with adaptive ones (e.g., emotional reappraisal and cognitive reflection). These results are in line with previous research suggesting that self-compassion may improve mental health by promoting adaptive emotion regulation processes (Inwood & Ferrari, 2018).

Second, the relationships between cognitive reappraisal (i.e., an adaptive emotional regulation strategy) and mindfulness and well-being variables strengthened after the MBSR program. By contrast, cognitive reappraisal became more strongly related to self-compassion variables after the CCT program. Emotional suppression (i.e., a maladaptive emotional regulation process) was negatively related to compassion toward others after both MBSR and CCT, and negatively related to mindfulness only in MBSR. These results offer new insights into how mindfulness and compassion practices enhance adaptive emotion regulation strategies (Garland et al., 2009; Jazaieri et al., 2014, 2018). For instance, our findings challenge traditional CBT models, which typically regard cognitive reappraisal as the core – and most important – emotion regulation strategy. Further, previous research has found that cognitive reappraisal, emotion suppression, mindfulness and self-compassion are the most common emotion regulation strategies facilitating well-being and mental health (Brockman et al., 2017; Inwood & Ferrari, 2018; Kraiss et al., 2020; Webb et al., 2012). Ultimately, mindfulness and compassion practices might be postulated as therapeutic ingredients for transdiagnostic protocols (e.g., the Unified Protocol; Barlow et al., 2018; Gilbert, 2014).

11.3.2 DIFFERENCES IN NODE CENTRALITY

As explained in the Chapter 5, the visual network representations offered in the network approach are complemented by different quantitative indexes of node centrality (i.e., importance and influence of each node within the network. Taken together, our results from Chapters 9 and 10 suggest that there are common and specific mechanisms of change in MBSR and CCT programs. Mindfulness (especially decentering, body awareness and non-attachment), self-compassion and well-being variables were among the most central nodes (i.e., the nodes most strongly connected to other nodes in the network) in both MBSR and CCT networks. This converges with previous research (Brito-Pons et al., 2018). However, well-being was more central in the MBSR network, whereas (self-) compassion variables were more central in the CCT network, which mirrors the specific ingredients/components of mindfulness and compassion programs, respectively (Hildebrandt et al., 2017; Singer & Engert, 2019). Furthermore, some of the same nodes displayed the highest centrality change after both programs (i.e., depression and some non-adaptive cognitive control measure such as brooding or thought suppression). Thus, we can conclude that some changes were shared by both MBSR and CCT. Yet, other changes seem specific to each program. In particular, centrality changes in attentional control seemed to be more pronounced after MBSR, whereas self-compassion increases in centrality were more notable after CCT.

11.3.3 DIFFERENCES IN NODE PREDICTABILITY

Predictability analysis (i.e., examining the degree to which the variance of a given node can be explained by all other nodes in the network) showed that the overall network predictability was quite high in both mindfulness and compassion networks. In both MBSR and CCT, the nodes with the highest predictability were mindfulness-related variables (especially decentering, body awareness and non-attachment), self-compassion, general well-being and psychopathology-related constructs (especially brooding and psychological distress). These predictability results provide an important additional characterization of MBSR and CCT networks, as they offer a measure of the controllability of each node in the network (Haslbeck & Fried, 2017). In other words, a high predictability of MBSR and CCT networks suggests that psychological variables can be controlled via neighboring nodes in the network. We found this to be the case for mindfulness, compassion, well-being and psychological distress variables. In the MBSR program, the nodes with the greatest predictability increases after the program were the mindfulness-related variables (decentering, body awareness, non-attachment, and reflection), while other mindfulness variables showed the greatest predictability decrease (i.e., observing, acting with awareness and attentional control). In the CCT program, the predictability of psychopathology-related constructs declined markedly after the program, especially for brooding, psychological distress and emotional suppression, as well as some mindfulness-related variables (i.e., describing and attentional control). Overall, these predictability results might provide a better marker for identifying the psychological nodes suitable for MBSR and CCT programs than the relative metrics of centrality (McNally, 2020).

11.3.4 Mindfulness and Compassion Communities

Finally, community detection analyses (i.e., different clusters of nodes within the network) revealed a meaningful network reorganization after the MBSR, but not after the CCT (where the communities remained largely intact after the program). In the case of MBSR, whereas the pre-MBSR communities were composed by rather heterogeneous variables, the communities of constructs that emerged after the MBSR seemed to be reorganized in a more psychologically meaningful way; they corresponded more closely with our a priori five theoretical domains of constructs (i.e., mindfulness, compassion, well-being, psychological distress and cognitive-emotional regulation; Goldberg et al., 2018; Gu et al., 2015; Hölzel et al., 2011; Malinowski, 2013; Wielgosz et al., 2019). These results offer a framework with which to study the hallmark psychological variables and heterogeneity in MBSR and CCT networks (Blanken et al., 2018), allowing us to identify the core nodes of a community (i.e., those with strong connections within the community) from the nodes belonging to multiple communities, also known as bridge nodes (Jones, 2017). An unexpected, but interesting, result was that self-compassion variables behaved like mindfulness-related variables in both programs. In other words, these self-compassion variables appeared clustered with mindfulness constructs instead of other compassion constructs (i.e., compassion for others and empathy). Given that mindfulness is a core component of self-compassion (i.e., self-compassion entails mindful awareness of the negative thoughts and emotions in order to embrace it with compassion), our results converge with previous work displaying similarities between both constructs (Neff & Dahm, 2015). Interestingly, the pre-CCT communities were very similar to those of the post-MBSR communities, which may support the foundational role of mindfulness for other meditation practices (Dahl & Davidson, 2019).

11.3.5 NETWORK ANALYSIS AND MBPS TARGETS

In recent years, the use of network analysis to analyze treatment-induced changes has expanded (see Chapter 5; Blanco et al., 2020; Blanken et al., 2019). The network approach could be a robust method to (1) explore the direct and indirect effects of MBP-induced changes, (2) highlight the pathways through which meditation produce its effects, and thereby (3) disentangle the underlying mechanisms of change. The Network-Based Interventions approach (Bak et al., 2016; Kroeze et al., 2017) suggests that the most central nodes represent preferential intervention targets, assuming that central nodes may promote the activation or deactivation of other nodes and the interactions between them (Hofmann et al., 2016). However, the evidence base confirming this hypothesis is still moderate (Castro et al., 2019), and there are some concern about which index of centrality is best in the behavioral sciences (Bringmann et al., 2019). Based on our centrality and predictability results, one could hypothesize that both mindfulness and compassion programs should focus on enhancing mindfulness-related skills (especially decentering, body awareness and non-attachment), and self-compassion (common humanity, self-kindness, and mindful self-compassion) which, in turn, are topologically connected to components of well-being. While the role of well-being nodes are more central in MBSR, the role of self-compassion skills is more central in CCT. Enhancements in these areas are be related to adaptive emotional and cognitive regulation processes (such as cognitive reappraisal, reflection and attentional control). Although both programs reduced psychological distress (i.e., stress, anxiety, and depression) and psychopathology-related constructs (i.e., rumination, thought and emotional suppression), the disconnection of these nodes was more pronounced in the CCT program. However, our data are based on cross-sectional networks (see Chapters 9 and 10). Longitudinal studies are needed to discern the directionality of these associations (i.e., determine causality). In future studies, we seek to compute causal networks based on the longitudinal data gathered from inter-session assessments and the ongoing 3-year follow-up.

11.3.6 THE 'PSYCHONECTOME' PERSPECTIVE

Beyond the specific results shown in Chapter 9 and 10, our network analyses provide proof-of-concept of the 'psychonectome'. Following what Guloksuz et al. (2017) called the wave of the '*-omics'* sciences (e.g., connectomics, genomics, symptomics; Fried et al., 2015), the psychonectome is defined as a complex ensemble of dependences between bio-psycho-social variables: i.e., a network modelling the relationships between different psychological variables (e.g., cognitive factors, personality traits, clinical symptoms, etc.), social variables (e.g., social support, stressful events, socio-economic status, etc.), and biological nodes (e.g., brain activity, hormonal levels, heart rate, etc.), to name a few. Thus, the psychonectome connects basic layers of elements at an individual level (e.g. neural activity networks, signs and symptoms) with elements external to individuals (e.g. stressors, environmental circumstances), and examines whether elements of some layers activate elements of other layers.

Furthermore, the psychonectome perspective may help inform the design of personalized interventions (Simon & Perlis, 2010), as it provides a sound methodological and conceptual framework to analyze complex interactions between bio-psycho-socio variables changes over time for particular individuals. This approach might help to promote a more holistic view of well-being and ill-being and to reduce artificial divisions of knowledge areas (e.g. psychology, medicine, economy, etc.). In addition, this approach would allow us to analyze whether and how specific interventions modify the structure of the psychonectome (e.g., by promoting adaptive relationships among the nodes).

Within the greater field of psychology, the psychonectome perspective understands the mind as a complex network of psychological constructs. Although most network studies have almost exclusively modelled symptoms as nodes in the network (i.e., single items often drawn from self-report questionnaires), preliminary evidence suggests that other psychological variables could be meaningfully incorporated in psychopathology networks (Jones et al., 2017; Letina et al., 2019), such as the stressful life events, positive functioning variables or behavioral measures, among others. In recognition of this, the psychonectome perspective moves beyond the symptoms, and encourages the use of psychological constructs (i.e., total scores) as nodes. We will introduce experimental measures (e.g., attentional bias to emotional information as measured by our AB task), biological parameters (e.g., EEG and EKG), and external factors (e.g., stressful life events or social support) to our networks in future analyses.

11.3.7 LIMITATIONS IN NETWORK ANALYSIS

As network analytic methods are still under development in psychology, we should interpret the present results with caution. Network replicability is one of the most important debates in the field (Forbes et al., 2019; Jones et al., 2019). Although network approach is especially valuable for exploratory work (Robinaugh et al., 2020), network analysis allows to mathematically analyze and quantify the relationships among the psychological variables involved in meditation practice while offering a visual representation of these relations. However, there is a risk of using network analysis with no clear theory-driven research plan.

In our study, the network stability was higher in MBSR networks than in CCT networks (i.e., in MBSR the network interpretation remains more stable when suffering from fewer observations and sampling variations). This may be due to the smaller sample size of the CCT study. Future studies should conduct 'confirmatory network analyses' in larger mindfulness and compassion samples to test the stability of our results. Furthermore, as it can be seen in Chapter 10, we improved our network analysis procedure in our second study using the CCT sample by combing state-of-art network analysis procedures with novel centrality metrics (e.g., Network Comparison Test, node predictability and bridge centrality). When we started the project (more than 5 years ago), the temporal time-series networks algorithms were beginning to be developed and validated in psychology, and the literature was dominated by cross-sectional networks. Thus, our plan in future publications is to conduct temporal time-series networks using the inter-session assessments data.

Despite these limitations, the set of studies presented in this dissertation provide novel results on the complex multivariate interactions of variables involved in mindfulness and compassion programs. The network analysis in general, and the psychonectome perspective in particular, are postulated as innovative ways to elucidate the mechanisms of change in meditation programs.

CHAPTER 12

CLINICAL IMPLICATIONS

Thus far, we have reviewed the literature on mindfulness and compassion programs and described our study methods, procedures, and results in detail. Now, it is important to take a step back and discuss potential clinical implications and applications of our findings. Clarifying the effects and mechanisms of different meditation programs will not only improve their efficacy, but may also promote the inclusion of meditation practice in broader psychological treatment protocols (Craig et al., 2008; Kladnitski et al., 2018). For instance, our results suggest that meditation practice could be introduced in broader CBT treatments to train some transdiagnostic therapeutic targets such as decentering, body awareness or self-compassion. Although some meditation ingredients are part of most 'third-wave' therapies (e.g., Dialectical Behavior Therapy or Acceptance and Commitment Therapy), these therapies have typically included general mindfulness components and have not adequately considered the specific mechanisms of change associated to these components, or the potential effects of other meditation types (e.g. compassion). It is our hope that these breakthroughs and insights from the meditation field help overcome the 'therapeutic impasse' of psychological interventions observed in the last years in which the efficacy levels of existing treatments have hardly increased (McNally, 2007).

Moreover, the similarities in attentional and psychological changes found after both mindfulness and compassion programs leads us to question the specificity of meditation programs. In fact, the specificity of psychological interventions has been an important issue in the past years (Ahn & Wampold, 2001). As previously mentioned, our results reveal several common effects and mechanisms in mindfulness and compassion standardized programs: 1) Both MBSR and CCT reduced similarly the attentional processing of emotional information (see Chapter 7); 2) Both programs were equally effective reducing psychological distress (i.e., stress, anxiety, and depression) and promoting well-being, and the RCI did not found significant differences between program in terms of clinically significant changes (see Chapter 8); and 3) mindfulness, self-compassion and well-being constructs were the most central nodes in both mindfulness and compassion networks (see Chapters 9 and 10). This overlap provides further evidence for the efficacy of CCT, as it shows comparable results between CCT and MBSR, a 'gold standard' meditation program (i.e., MBSR) which that has shown efficacy in a wide range of RCTs and meta-analyses (Goldberg et al., 2018; Hedman-Lagerlöf et al., 2018; Wielgosz et al., 2019).

Several potential factors could explain the shared effects in both MBPs: 1) Both programs have some common goals, e.g., mind training as a way to reduce psychological suffering while enhancing well-being and human flourishing (Jinpa, 2019), or the training of attentional control though meditation practice; 2) The programs also have common non-specific factors, such as the therapeutic alliance, expectations and motivation biases, instructor characteristics, spontaneous improvements, group cohesion, and professional's care, among others (Lambert & Barley, 2001; Laska et al., 2014); and 3) in MBSR (self) compassion is taught implicitly as an attitudinal foundation (Brito-Pons et al., 2018; Neff & Dahm, 2015), but at the same time, mindfulness is formally practiced in the first session of the CCT as a foundation for subsequent practices (Jinpa, 2010). These commonalities makes more difficult to draw a precise line in the expected effects of different meditation types (Grossman, 2019).

Another plausible explanation for the similar effects of MBSR and CCT could be that different mechanisms of action lead to comparable results (see Chapters 8, 9 and 10). In other words, it seems that each program operates through different pathways to attain the same goals (i.e., reduce psychological distress and promote well-being). The similarities in some intervention outcomes may obscure important differences in the operating mechanisms. For instance, cognitive therapy and antidepressants appear to have similar short-term effects achieved through different brain pathways (DeRubeis et al., 2008). A similar effect is found when comparing the efficacy of mindfulness and aerobic exercise: both improve mood and sleep quality, although the mechanisms through which they produce these changes are distinct (Rosenkranz et al., 2019). Specifically, improvements in regulation of autonomic arousal, decreased worry and rumination, and increased acceptance are operative in the case of mindfulness, whereas improvements in thermoregulatory processes, cytokine release, and circadian rhythms are most operative in the case of aerobic exercise.

The similarities between mindfulness and compassion programs may also result from the fact that our results are based on average sample scores, instead of the individual-level scores. The absence of differences at the group level does not rule out differences at the individual level. On an applied basis, we as psychologists are interested in which intervention is most beneficial for a specific person, and our clinical experience shows us that even the best empirically validated intervention is not effective for everyone. In our case, some important questions arise: Who can benefit from MBPs? For whom, when, how, and why meditation programs are effective? These questions have been originally addressed from the framework of 'personalized medicine' (Hamburg & Collins, 2010), and brings us closer to the 'personalized psychological interventions' (Simon & Perlis, 2010) which aim to analyze the baseline characteristics of each person as predictive factors of the differential response (Cuijpers et al., 2012). This field shows promise, as it has already developed new analytic tools for selecting the optimal intervention for unique individuals according to their personal characteristics and circumstances. In future lines of study, we are planning to incorporate machine learning algorithms to our network approach to analyze the baseline predictors of efficacy in MBPs (i.e., moderators of change); our hope is that this method may eventually allow us to develop optimal meditation programs for each individual.

However, our experimental design does not allow us to properly examine common and specific program effects. Double-blind RCTs with active control groups are needed to identify the specific active ingredients and the common non-specific factors at play in meditation programs (Davidson & Kaszniak, 2015; Rosenkranz et al., 2019; Van Dam et al., 2018). Dismantling and additive component studies are also needed (Bell et al., 2013), as they would help identify which specific active ingredients contribute to differential outcomes and the magnitude of changes in multicomponent interventions. In our case: What are the most effective components within the MBSR and the CCT programs? Is the focused attention to the breath component more, less or equally effective than the yoga stretches? To date, there are few dismantling and additive studies in the field of meditation research (Lindsay et al., 2018; Williams et al., 2014). From an integrative framework, we could combine the psychonectome perspective and personalized framework with the component studies; this would enable us to design meditation programs that take into account significant moderators associated with the efficacy of the program for each person together with the most effective active ingredients from different MBPs (for instance, the most effective mindfulness and compassion techniques). At present, this seems a distant goal. However, we hope that the future may see 'tailor-made meditation programs' that are empirically validated and adapted to the characteristics and circumstances of each person.

CHAPTER 13

WHAT ARE THE NEXT STEPS? LIMITATIONS AND FUTURE STUDIES

The present doctoral dissertation has tried to overcome some of the major limitations observed in previous meditation studies. Nevertheless, our results must be considered in the light of some methodological limitations, broadly explained in the different dissertation articles (from Chapters 7 to 10). In this section, we will first address some general study limitations, then discuss paths for future research to overcome these limitations, as well as the next steps in our project.

Due to the naturalistic design of our trial, it was infeasible to randomly assign participants to either MBSR or CCT. This lack of randomization, however, may have led to self-selection biases; specifically, certain pre-existing individual differences may help explain program choice and, thus, the observed results (e.g. motivation or personality traits related the decision of practice meditation). Accordingly, we cannot isolate MBSR and CCT as the unique sources of the beneficial changes resulting from the respective programs.

Furthermore, unlike patients in placebo-controlled drug trials, participants were not "blind" to the study condition. Our participants were, however, blind to the specific aims of the study. As previously discussed, RCTs are not exempt of limitations, and the freedom to choose one's preferred intervention is a strong predictor of therapeutic adherence and engagement (Lindhiem et al., 2014; Rennie et al., 2007). Our method does, however, aim to minimize this limitation. First, the strategy of comparing two standardized active programs likely reduces the influence of common non-specific factors, such as motivation, demand characteristics or differences between experts and novices. Second, the use of large sample sizes and baseline-differences as covariates in some analyses help counteract potential biases arising from the lack of randomization. To meet established clinical research standards, future research will need to further address these methodological limitations by using RCT designs with rigorous control conditions. Furthermore, we have also evaluated a waiting-list control group for a replication of the Attentional Blink study, in order to analyze the effects of the practice in the task.

Another important limitation in the studies presented, which will be adequately addressed in future publications, is that only pre- and post-intervention information was analyzed. The cross-sectional and two-time points approximation in the current dissertation should be viewed as a first step to better understand the effects and mechanisms in MBPs. Most previous studies analyzing trait differences compare long-term meditators with novices; however, some pre-existing individual differences related to the decision to invest time in meditation practice could help explain such differences. For this reason, long-term longitudinal studies are needed to evaluate the predictors of long-term practice (Davidson & Kaszniak, 2015).

With regards to our sample characteristics, some baseline features may have affected our results; e.g., highly educated sample, the use of a non-clinical sample or the high homogeneity of the sample (i.e., the full sample was recruited in the same organization and the same city). Furthermore, our sample included participants with and without previous meditation experience from different traditions. Although this particular baseline status could be a relevant moderator of the results, our naturalistic design and sample adequately reflect the 'true' characteristics of participants who attend standardized meditation programs in real life settings.

Future studies should also seek to replicate our results with other meditation types (e.g., deconstructive family; Dahl et al., 2015), meditation traditions (e.g. Sufi tradition), meditation experience (e.g., novice vs experts), and practice settings (e.g. retreats, group format, individual practice). Furthermore, the increasing use of new technologies and the rise of internet and smartphone-based interventions (Andersson et al., 2019) have opened new possibilities for disseminating and assessing the MBPs, as well as for scaling-up the availability of meditation practice. The delivery of MBPs over the internet and mobile apps has increased exponentially in the last years, and further research on key methodological challenges is needed (Davidson & Dahl, 2018; Dimidjian et al., 2014).

Some studies have also found significant individual variance in their 'state changes' during the MBPs that predict the pre-post changes in trait outcomes (Kiken et al., 2015). From a neurobiological point of view, the recurrent activation of certain specific brain networks during the meditation practice (i.e. state changes) leads to more stable functional and structural brain changes (i.e., trait changes; Garland, Fredrickson, et al., 2010). Thus, future studies should analyze how the individual trajectories of state measures predict changes in trait meditation measures. Intensive longitudinal assessment methods, such as Ecological Momentary Assessment (Shiffman et al., 2008), may produce more reliable and ecological results and may be more appropriate for investigating mechanisms of action in MBPs (Enkema et al., 2020).

Another important area of future research involves the potentially adverse effects of meditation practice (Cebolla et al., 2017; Lindahl et al., 2017; Van Dam et al., 2018). Although meditation practices tend to be beneficial for certain people under certain conditions, there may be inflection points at which positive effects could turn negative, following an inverted U-shaped trajectory (Britton, 2019). Although one might think that meditation practice is free of adverse effects, participants in a MBP usually report different ‘unpleasant reactions’, such as anxiety, disorientation during the formal practices, or cognitive depletion in early stages of the training (Creswell, 2017). Furthermore, a few studies have documented more severe adverse effects, such as the onset or exacerbation of depersonalization symptoms, panic, psychosis, mania, trauma-related symptoms (e.g. re-experimentation), or even suicidal ideation (Lindahl et al., 2017; National Center for Complementary and Integrative Health, 2016; Van Dam et al., 2018). Despite the CONSORT guidelines (Moher et al., 2001), fewer than 25% of meditation trials actively assess adverse effects (Van Dam et al., 2018). In the present doctoral dissertation, we have included the Reliable Change Index (see Chapter 8) to describe our data in terms of clinically meaningful gains and deterioration cases.

Finally, the issue of practice dosage is one of the most important practical questions to understand the effects of MBPs (Creswell, 2017; Wielgosz et al., 2019). According to Buddhist tradition, most benefits associated with meditation practice need several years of regular practice to flourish (Goldstein, 2003). Although the 8-week structure and duration of the intervention is acceptable for some participants, they may not be feasible for others (Parsons et al., 2017). More research is needed to address key issues such as duration, intensity, or spacing of the practice. Future studies should determine the optimal practice length and regimen for a particular individual according to their personal characteristics; this can be done by examining whether home practice data moderates the effects of MBPs. It is important to remember that our conclusions are drawn from two brief standardized mindfulness and compassion programs in secular contexts; future studies should seek to replicate these results in long-term mindfulness and compassion practice, intense intervention modalities (i.e., meditation retreats; (Khoury et al., 2017), or even in brief experimental inductions (Schumer et al., 2018).

CHAPTER 14

CONCLUSIONS

I will always remember that the final stretch of my PhD coincided with the Coronavirus Disease 2019 (COVID-19) outbreak. In fact, I am writing this discussion during the mandatory quarantine period, contemplating a deserted Madrid city. As a psychologist deeply committed to the cultivation of well-being and human flourishing, I have been thinking a lot on how this global challenge can bring out the best in us. And now, more than ever, I realize that meditation practice is a powerful tool, and that many of the psychological effects and mechanisms mentioned in this dissertation have become especially meaningful during this pandemic.

Times like these cause stress and worries about an uncertain future: Will my family and loved ones be safe? How long is this going to last? If this pandemic has taught us anything, it is that we cannot always control everything that happens around us, and that everything we cherish may change without warning, reminding us the impermanence of things. Our studies support the idea that one way to face this psychological distress, rumination, and worry is by training of mindful awareness, paying attention to our thoughts, emotions, sensations and motivations that guide our behaviors, with an attitude of acceptance and a healthy psychological distance. In times of sickness, we have learned that practicing 'physical distancing' could be an act of kindness and compassion, reducing the likelihood of exposure ourselves and others at risk to contagion. The spread of coronavirus around the word did not honor genders, nationalities or ethnics; rather, it serves as a reminder of our common humanity, and how extraordinarily interconnected we are. All these skills have had a key role in this dissertation, and now more than ever one understands its applicability in everyday life.

COVID-19 is also a poignant reminder of the need to invest in science. We cannot escape the reality that this project has been carried out with limited funds, except for the invaluable support and infrastructure of Nirakara Lab and INVENTAP. Future funding will be critical to overcome some of aforementioned limitations and promote the implementation of well-control RCTs in large samples. Further, working closely with brilliant researchers and clinicians, and I have had the privilege to do, will allow me to further develop my activities as researcher to move forward in this field.

This doctoral dissertation was inspired by the fascinating dialogue between contemplative traditions (providing the wisdom and ancient knowledge) and the scientific community (providing the tools to empirically study this knowledge). In fact, science has become a major vehicle through which interest in meditation has expanded to thousands of Western communities, and MBPs have been the maximum exponents of this movement. The ultimate goal of research is to respond to human problems and needs, and the increase of social interest in meditation practice in different sectors of society (e.g., health, education, politics) is indubitable. From its early exploratory stage, the field of meditation has now reached a more matured state; we are now in a privilege position to closely examine all we have learned so far, using this opportunity to refine our questions and hypotheses. The study limitations notwithstanding, we strongly believe that the present dissertation offers valuable contributions to the existing literature. Thankfully, the contemplative traditions have a large reserve of ancient knowledge 'unexplored' in their potential translation into secular contexts and empirically validated interventions. There still remains much to be done, and this is only the beginning.

Table 6. Dissertation Summary
• Overall, one of the main conclusions to be drawn from our studies is that there are some common effects and mechanisms shared by mindfulness and compassion standardized programs, whereas others are specific to each type of practice.
• Whereas both programs yielded significant increases in mindfulness and compassion skills, present-moment awareness changes were significantly larger in the MBSR program, whereas socio-emotional changes were larger in the CCT program.
• Both mindfulness and compassion programs were equally effective reducing psychological distress and promoting well-being. However, the mechanisms of change through which mindfulness and compassion achieve these outcomes were different, as evidenced by both advanced mediation analyses and novel network analysis.
• Mindfulness and compassion programs showed different network features (e.g., self-compassion, emotion regulation or rumination), as well as differences in centrality and predictability metrics.
• The results of our AB task also showed that meditation practices improved early stages of emotional processing by increasing the flexibility of resources allocation. Meditation may reduce the attentional biases to negative stimuli by broadening the attentional field, enhancing the processing of positive and neutral stimuli, and promoting a less biased attention of all information.
• Therefore, attentional processing of emotional information is postulated as a transdiagnostic mechanisms and as an important future direction to investigate.
• These results also highlight the potential for drawing on meditation practice to enrich the field of clinical psychology.

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ANNEXES

SUPLEMENTARY MATERIALS – ATTENTIONAL BLINK

Brief meditation trainings improve performance in the Emotional Attentional Blink

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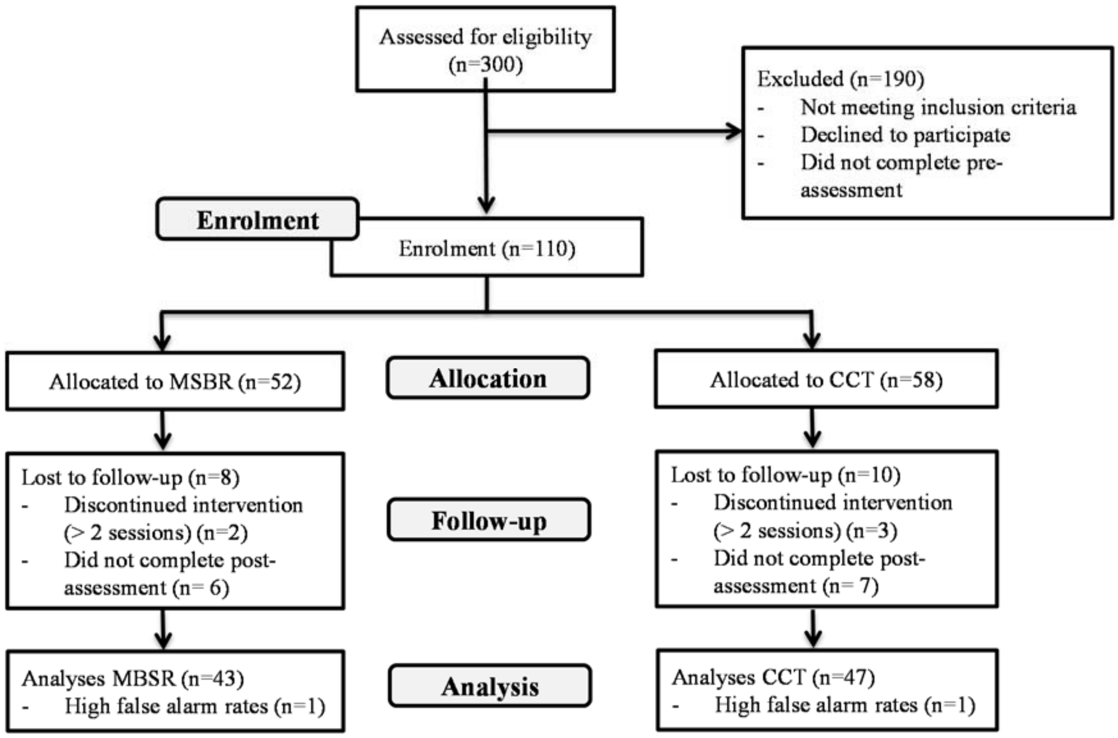
Supplementary Methods and Results

Participants

A full flow chart of participants is shown in Supplementary Figure 1.

Supplementary Figure 1. Participation flow diagram.



Statistical Analyses

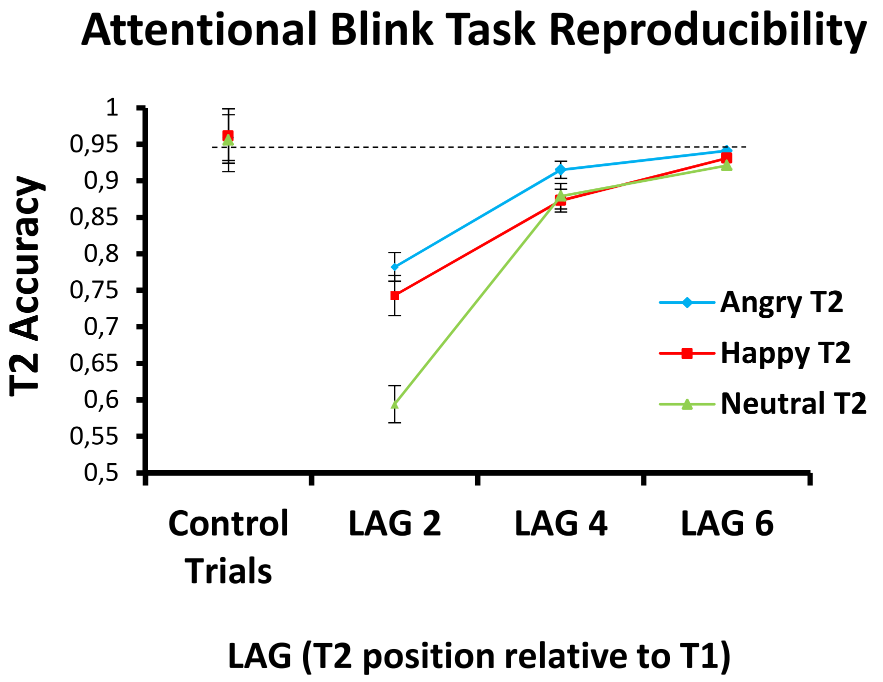
It is important to keep in mind that the AB task is based on four main assumptions: 1) The AB effect is an index of temporal attentional limitations and by definition the AB is a lag-dependent effect on T2 performance: AB can be genuinely detected when T2 accuracy is reduced at short (i.e. within 500 ms) relative to long T1-T2 lags (i.e. function's slope; MacLean & Arnell, 2012). Thus, only those ANOVA interactions in which the Lag is involved are theoretically meaningful; 2) as we are studying the changes produced after two standardized meditation programs (i.e. MBSR and CCT), interactions of Time x Lag are necessary to indicate that the AB has been modulated by the interventions, and only those ANOVA interactions in which the Time is involved are theoretically meaningful; and 3) performance at long lags (lag 6 in our case) is no longer affected by the effect of T1 (i.e. post-T1 impairment) and should reach the asymptote level measured by the control trials (MacLean & Arnell, 2012). In other words, T2 performance at lag 6 trials should not differ from performance at T1-absent control trials (base line).

Results

Task reproducibility (tests of assumptions)

To assess if the task designed, using emotional faces as targets and scrambled faces as distractors, was able to elicit the classical U-shaped time course observed in the standard AB task (Raymond, Shapiro, & Arnell, 1992), a three-way repeated measures ANOVA (T1 Emotion x T2 Emotion x Lag) was carried out for the pre-intervention scores (see Figure 3). As hypothesized, Lag ($F_{(1.47, 130.52)} = 202.17$, $p<.001$, $\eta^2_{partial} = .69$; $1\text{-}\beta = 1.00$), T2 emotion x Lag ($F_{(3.01, 267.67)} = 48.31$, $p<.001$, $\eta^2_{partial} = .35$; $1\text{-}\beta = 1.00$), and Lag x T1 emotion x T2 emotion ($F_{(5.94, 528.45} = 5.03$, $p<.001$, $\eta^2_{partial} = .05$; $1\text{-}\beta = 0.99$) had a significant effect on T2 accuracy. Thus, the Emotional AB task was able to fulfill the first three assumptions mentioned above.

Supplementary Figure 2. Attentional Blink Task Reproducibility. The error bars represent the standard error for each 95% confidence intervals.



To check the third assumption (i.e. T2 performance at lag 6 trials should not differ from performance at T1-absent control trials) a 2 (Trial Type: single-target vs. double-target at Lag 6) x 3 (Emotion: angry, happy and neutral) x 2 (group: MBSR and CCT) x 2 (time: pre and post) mixed ANOVA on T2 accuracy was carried out. A significant Trial type x Time interaction was found ($F_{(1,\,88)} = 15.19$, $p < .05$, $\eta^2_{partial} = .15$; $1\text{-}\beta = 0.97$). Pairwise Bonferroni-corrected comparisons indicated that there were differences between single and double trials at pre-intervention (single-target trials had higher accuracy than double-target trials), but these differences disappeared at post-intervention. The Trial x Time x Group interaction was not significant ($F_{(1,\,88)} = 2.48$, $p > .05$), indicating that there was no difference between meditation programs, or type of trials, at any testing time, on T2 accuracy between single and double trials. Neither Trial x Emotion x Time interaction ($F_{(2,\,176)} = 1.20$, $p > .05$) nor Trial x Emotion x Time x Group interaction ($F_{(2,\,176)} = 1.44$, $p > .05$) reached significance, reflecting that there were no differences between meditation programs on simple-target or double-target trials at lag 6 for any emotions.

Supplementary Table 1. T2 accuracy after having correctly identified T1. Means and Sd. Note: MBSR=Mindfulness-Based Stress Reduction; CCT= Compassion Cultivation Training.

		MBSR						**CCT**					
		PRE – T2			**POST – T2**			**PRE – T2**			**POST – T2**		
		Angry	**Happy**	**Neutral**	**Angry**	**Happy**	**Neutral**	**Angry**	**Happy**	**Neutral**	**Angry**	**Happy**	**Neutral**
Lag 2 -T1	**Angry**	.69 (.25)	.72 (.25)	.54 (.33)	.79 (.20)	.74 (.27)	.68 (.25)	.68 (.24)	.74 (.25)	.51 (.27)	.73 (.24)	.81 (.24)	.67 (.28)
	Happy	.77 (.23)	.71 (.25)	.61 (.29)	.88 (.16)	.84 (.18)	.73 (.26)	.85 (.15)	.74 (.23)	.64 (.23)	.87 (.14)	.79 (.25)	.74 (.26)
	Neutral	.82 (.19)	.74 (.21)	.67 (.25)	.88 (.17)	.82 (.18)	.78 (.24)	.83 (.16)	.82 (.19)	.61 (.25)	.89 (.13)	.84 (.16)	.72 (.28)
Lag 4 - T1	**Angry**	.88 (.14)	.81 (.22)	.86 (.20)	.91 (.12)	.89 (.16)	.91 (.17)	.91 (.11)	.87 (.18)	.83 (.18)	.92 (.11)	.89 (.18)	.90 (.14)
	Happy	.94 (.14)	.87 (.15)	.88 (.18)	.94 (.13)	.92 (.13)	.91 (.14)	.95 (.08)	.92 (.16)	.85 (.17)	.92 (.11)	.93 (.15)	.90 (.14)
	Neutral	.90 (.17)	.87 (.18)	.94 (.11)	.94 (.14)	.93 (.13)	.96 (.09)	.90 (.10)	.88 (.13)	.90 (.16)	.93 (.08)	.91 (.13)	.94 (.12)
Lag 6 – T1	**Angry**	.93 (.09)	.92 (.12)	.90 (.12)	.94 (.08)	.96 (.08)	.96 (.08)	.92 (.12)	.92 (.14)	.93 (.11)	.94 (.11)	.94 (.12)	.94 (.10)
	Happy	.96 (.08)	.92 (.11)	.93 (.10)	.96 (.08)	.95 (.08)	.95 (.09)	.96 (.07)	.92 (.16)	.92 (.13)	.97 (.06)	.93 (.12)	.96 (.06)
	Neutral	.93 (.12)	.95 (.07)	.93 (.09)	.95 (.07)	.93 (.10)	.96 (.07)	.93 (.08)	.95 (.08)	.91 (.17)	.96 (.07)	.96 (.08)	.93 (.12)

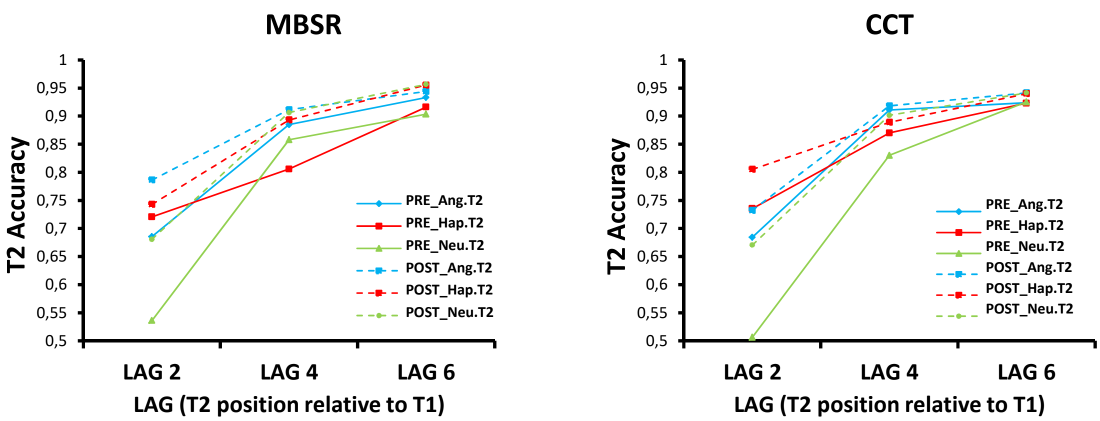
ANOVA collapsing T1 emotion

A relevant feature of these results is that all the interactions in which T1 Emotion was involved were not significant, indicating that T1emotion did not show a significant effect on T2 accuracy after the meditations programs. For this reason, we decided to delete the "T1 Emotion" factor, to simplify subsequent analyses, following the same procedure used by Bach, Schmidt-Daffy, & Dolan (2014). A series of 3 (T2 emotion: angry, happy and neutral) x 3 (T1-T2 Lag: 2, 4 and 6) x 2 (Group: MBSR and CCT) x 2 (Time: pre and post) mixed ANOVA was carried out for every T1 emotion:

a) Identification of T2 emotional face after an Angry T1 (see fig. 6)

There was a marginal Lag x T2 Emotion x Time x Group interaction ($F_{(3.09, 272.06)}$ = 2.28, p =.06, $\eta^2_{partial}$ = .03; 1-β = .66), reflecting that there were differences between the meditation programs in the Emotional AB effect when this was preceded by an angry T1. Pairwise Bonferroni-corrected comparisons indicated that there were some differences between MBSR and CCT: 1) Angry T2: while the MBSR reduced the AB effect for the short lag after the intervention, no differences were observed in the CCT after the intervention; 2) Happy T2: no significant differences between programs were found; 3) Neutral T2: while the MBSR reduced the AB effect for the short lag after the intervention, the CCT does it for short and medium lags.

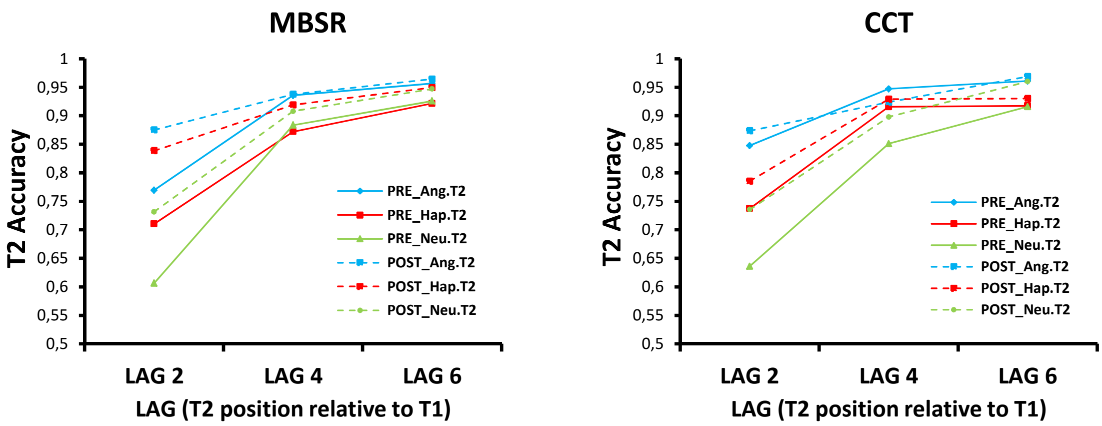
Supplementary Figure 3. Emotion T2 identification after Angry T1. Note: MBSR=Mindfulness-Based Stress Reduction; CCT= Compassion Cultivation Training.



b) Identification of T2 emotional face after a Happy T1 (see fig. 7)

The interaction Lag x T2 Emotion x Time x Group interaction was not significant ($F_{(3.33, 293.22)} = .09$, $p > .05$), reflecting that no differences were found between the meditation programs in the Emotional AB effect when it was preceded by a happy T1. However, a significant Lag x Time x Group interaction was found ($F_{(1.68, 147.73)} = 4.59$, $p < .05$, $\eta^2_{partial} = .05$; $1\text{-}\beta = .72$), indicating that there were differences between both meditation programs on the AB effect (i.e. Lag-dependent effect) when it was preceded by a happy T1. Pairwise Bonferroni-corrected comparisons indicated that while the MBSR reduced the AB effect after the intervention in all the lags, no differences were observed in the CCT for the medium and long lags.

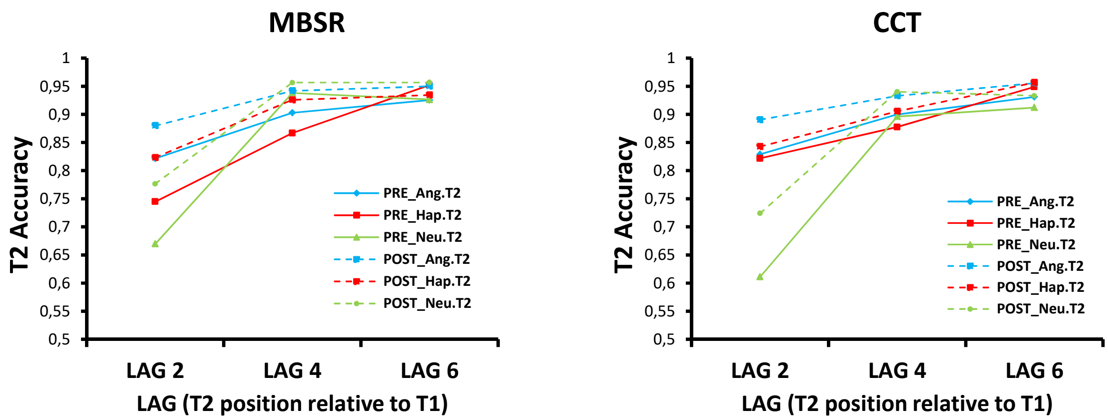
Supplementary Figure 4. Emotion T2 identification after Happy T1. Note: MBSR=Mindfulness-Based Stress Reduction; CCT= Compassion Cultivation Training.



c) Identification of T2 emotional face after a Neutral T1 (see fig. 8)

The Lag x T2 Emotion x Time x Group interaction was not significant ($F_{(3.53, 310.16)} = 1.32$, $p > .05$) reflecting no significant differences between the meditation programs on the Emotional AB effect when it was preceded by a neutral T1. Neither the Lag x Time x Group interaction reached significance ($F_{(1.71, 150.11)} = .44$, $p > .05$), indicating that both programs reduced similarly the AB effect after a neutral T1.

Supplementary Figure 5. Emotion T2 identification after Neutral T1. Note: MBSR=Mindfulness-Based Stress Reduction; CCT= Compassion Cultivation Training.



ANCOVA with age as a covariate

Furthermore, an ANCOVA (T1 x T2 x Lag x Time x Group) was carried out using age of participants as a covariate to examine whether baseline age differences between groups could explain the differences in the AB task. Age did not show a significant effect as covariate in the analysis (F (1, 87) = 3.74, p >.05) and the full interaction remained not significant, as in the mixed ANOVA presented previously.

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SUPLEMENTARY MATERIALS – MEDIATORS OF CHANGE

Not all types of meditation are the same: Mediators of change in mindfulness and compassion meditation interventions

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Supplementary Methods and Results

Statistical Analyses

Given that some analyses were multivariate (i.e., multiple mediation), we used G*Power (v. 3.1) to calculate sample size to test linear multiple regressions including all the predictors in the model. With a small effect size of 0.10 (Brito-Pons et al., 2018), analyzing models that could include up to 20 predictors (including mediators and covariates), and an alpha of .05, it would be needed at least 324 participants to detect significant effects at 95% power.

Statistical analyses were conducted only for participants who completed both pre and post assessments (i.e., completers), having attended at least 6 of the 8 sessions (i.e., 75% of the program). As the software used for the online assessment was programmed to force individuals to respond to all items to finish the questionnaire, there were no item-level missing values. For this reason, construct-level missing values were calculated only for those participants who did not complete the post intervention assessment (i.e., 27.8%). The diagnosis of the random pattern of missing data was carried out by using the Little MCAR test (χ^2 (1111) = 130.95, $p > .05$), concluding that missing data were completely at random. Furthermore, participants who completed pre-post assessment did not differ significantly from those who completed only the pre-assessment on the demographic variables (i.e., gender, age, education and nationality, all *ps* >.05). For all these reasons, and taking into account the relatively large sample size of the study with pre and post complete data (i.e., 438 individuals), we opted not to impute missing data.

First, a 2 (program: MBSR vs CCT) x 2 (time: pre vs post) mixed ANOVA was used to examine whether the MBSR and CCT produced significant changes in outcomes and mediators. For all analyses: a) ANOVA assumptions were tested at baseline: normality was assessed by Shapiro-Wilk test, homoscedasticity was assessed by Levene's test, independence was assessed by non-parametric Runs test, and sphericity was assumed because measure of variance between pairs had only two levels; b) Partial Eta square effect size was calculated for the ANOVA interactions and Cohen's d effect sizes and its corresponding 95% Confidence Intervals (CI) were also computed for within-group comparisons based on Botella and Sánchez-Meca (Botella and Sánchez-Meca, 2015); c) power analysis was carried out for each ANOVA effect; and d) pairwise Bonferroni-corrected comparisons were used for post-hoc analysis.

Second, a mixed ANCOVA tested whether the outcomes and mediators changed after we controlled for previous experience with meditation and age of participants. The ANCOVA included program (i.e., MBSR vs CCT) as between-subject factor, time (pre vs post) as within- subject factor and previous meditation experience, practice during the program and age as continuous covariates.

Thirdly, following Britton's (Britton, 2019) suggestions to improve individual-level analysis and the detection of potential adverse effects in meditation studies (Cebolla et al., 2017), we computed the Reliable Change Index (RCI; Jacobson et al., 1999; Jacobson & Truax, 1992). The RCI characterizes changes in outcomes (i.e., stress, anxiety, depression, and well-being) in terms of clinically meaningful gains and deteriorations. In order to determine the type of clinical change produced, all participants were classified into four categories according to their cutoff point and the RCI scores: 1) *No change*: when the post-intervention score does not reach the functional cut-off and the change is no reliable; 2) *Recovered*: when post-intervention scores is located within the range of the functional distribution and the change is reliable; 3) *Improved*: when the change is reliable but post-intervention scores does not reach the functional level; and 4) Deteriorated: when the post-intervention score does not reach the functional cut-off and the post-intervention score is worse than pre-intervention score.

Finally, mediation analyses were performed in order to examine whether mindfulness and compassion changes after the program mediated the efficacy of the programs on psychological distress and well-being. Both simple mediation (i.e., one mediator) and multiple mediation (i.e., more than one mediator simultaneously) were conducted on change scores (i.e., post-pre scores), using pre-intervention outcomes scores and pre-intervention mediators scores as covariates in the analysis to control for baseline differences between groups. Thus, in our analyses, X was the program (coded 0 for MBSR and 1 for CCT), Y was the post-pre changes in outcomes measures (psychological distress and well-being), M was the post-pre changes in mediation measures (mindfulness and compassion-related measures), and CV were pre-intervention outcomes and mediators scores for each analysis (i.e., covariates). Unstandardized regression coefficients *(b)* were computed for each path in the mediation model: *path a* represents the prediction of X on M, *path b* represents the prediction of M on Y, *path c* represents the total prediction of X on Y and *path c'* represents the direct prediction of X on Y controlling the effect of M. Furthermore, the indirect effect of X on Y through M was computed as the *path a* and *path b* product *(ab)*, of which 95% Bias Corrected Confidence Intervals (BC 95% CI's) were based on 10.000 bootstrapped samples. In simple mediation only one indirect effect was calculated while in multiple mediation several indirect effects were calculated for each mediator in the model (taking the correlation with the other mediators into account). For all the mediation analyses: a) data were screened before the mediation following Tabachnick, Fidell, & Ullman (Tabachnick et al., 2007) recommendations, including outliers screening (using Mahalanobis, Cooks and Leverage distances), multicollinearity, normality, linearity, homogeneity, homoscedasticity and independence of errors; b) Post-hoc pairwise contrasts of the specific indirect effects were used in multiple mediation to examine the relative magnitude between the multiples predictors; and c) R^2 was also used as a measure of the effect size in those mediation models that were significant.

Results

Hypothesis 1 and 2: Changes in outcomes and mediators after MBSR and CCT programs (Mixed ANOVA, ANCOVA and RCI).

The normality assumption was fulfilled only for FFMQ, EQ, MAIA, and SCS (Shapiro-Wilk tests > 0.01). Homoscedasticity assumption (Levene's test > 0.01) and independent assumption were fulfilled for all the measures (Runs test > 0.01). Given that only the assumption of normality was violated for some measures, the ANOVA should remain sufficiently robust and reliable (Schmider et al., 2010).

Supplementary Table 1

The RCI analyses indicated that the groups did not differ in the proportion of participants achieving clinically significant gains on measures of stress ($\chi^2_{(1)} = 1.25$, $p = .26$), anxiety ($\chi^2_{(1)} = 2.31$, $p = .13$), depression ($\chi^2_{(1)} = .68$, $p = .41$), or well-being ($\chi^2_{(1)} = .87$, $p = .35$). The MBSR had a nonsignificant advantage over CCT on all measures: stress (70.4% vs 65.2%), anxiety (52.5% vs 44.9%), depression (60.4% vs 56.3%), and well-being (76.8% vs 72.8%).

Secondly, no significant differences between MBSR and CCT were found either in the reliability of change in stress ($\chi^2_{(2)} = 3.25$, $p = .20$), depression ($\chi^2_{(2)} = 2.52$, $p = .28$), and well-being ($\chi^2_{(2)} = 4.42$, $p = .11$), and marginal differences were found in anxiety ($\chi^2_{(2)} = 5.49$, $p = .06$). The comparison of MBSR vs CCT revealed similar percentages of participants achieving a reliable change in stress (37.5% vs 29.1%), anxiety (15.4% vs 12.7%), depression (24.6% vs 21.5%), and well-being (52.9% vs 42.4%).

Finally, Figure 2 shows that no significant differences between MBSR and CCT were found in clinical change in stress ($\chi^2_{(3)} = 3.42$, $p = .33$), depression ($\chi^2_{(3)} = 3.23$, $p = .36$), and well-being ($\chi^2_{(3)} = 4.52$, $p = .21$). Yet, for anxiety, the MBSR program showed significantly less participants with no changes than the CCT [41.1% vs 53.2%; ($\chi^2_{(3)} = 8.76$, $p = .033$)].

Supplementary Figure 1

***Hypothesis 3.1*: mediators of change in MBSR and CCT (single mediation models).**

Assumption tests revealed low additivity and multi-collinearity (i.e., correlation between predictors lower than .80), normal distribution of predictors (i.e., regression standardized residuals centered around zero in the histograms), a linear relationship between predictors and dependent variables (i.e., regression standardized residuals dots on the line in the normal P-P plots), homogeneity and homoscedasticity (i.e., errors centered around zero and distributed across all the values of the DV in the standardized residual scatter plots) and independence of errors (i.e., the scores of one participant are not based on the scores of other participants). Finally, we screened for multivariate outliers by following the two out of three rule: participants with at least two indices (i.e., Mahalanobis, Cooks and Leverage distances) higher than the cut-off was removed from the analyses.

It was observed that most of the a-path, b-path and indirect effects a*b-path were statistically significant after controlling by baseline differences. However, the total effect (c-path) and direct effects (c'-path) of the programs on outcomes were not significant, indicating that the effects of the MBSR and CCT programs on psychological distress and well-being were totally mediated by mindfulness and compassion-related measures.

Supplementary Table 2

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Supplementary Table 1. Means, standard deviations and within-group effect sizes in MBSR and CCT programs.

	MBSR			CCT		
	Pre *M (SD)*	**Post *M (SD)***	**Within-Group *d* (95% CI)**	**Pre *M (SD)***	**Post *M (SD)***	**Within-Group *d* (95% CI)**
FFMQ Observing	3.50 (0.82)	3.97 (0.70)	-0.56* (-0.46, -0.67)	3.79 (0.71)	4.10 (0.71)	-0.44* (-0.31, -0.57)
FFMQ Describing	3.57 (0.77)	3.75 (0.73)	-0.24* (-0.14, -0.34)	3.57 (0.75)	3.74 (0.72)	-0.24* (-0.14, -0.34)
FFMQ Acting Awareness	2.82 (0.76)	3.27 (0.74)	-0.60* (-0.48, -0.71)	2.96 (0.67)	3.33 (0.67)	-0.55* (-0.41, -0.70)
FFMQ Non-Judgment	3.42 (0.91)	3.98 (0.72)	-0.61* (-0.50, -0.73)	3.64 (0.88)	4.10 (0.68)	-0.52* (-0.37, -0.68)
FFMQ Non-Reactivity	3.05 (0.63)	3.51 (0.60)	-0.73* (-0.59, -0.86)	3.24 (0.59)	3.59 (0.50)	-0.58* (-0.41, -0.76)
FFMQ Mindfulness total	3.27 (0.54)	3.70 (0.49)	-0.78* (-0.67, -0.90)	3.44 (0.51)	3.77 (0.46)	-0.65* (-0.50, -0.80)
EQ Decentering	3.19 (0.61)	3.75 (0.57)	-0.92* (-0.78, -1.05)	3.35 (0.56)	3.74 (0.51)	-0.69* (-0.53, -0.85)
MAIA Noticing	3.22 (0.98)	3.79 (0.83)	-0.58* (-0.46, -0.70)	3.48 (0.95)	3.79 (0.84)	-0.32* (-0.20, -0.45)
MAIA Not-Distracting	2.33 (0.87)	2.74 (0.95)	-0.47* (-0.32, -0.62)	2.52 (0.87)	2.75 (0.91)	-0.26* (-0.08, -0.44)
MAIA Not-Worrying	2.53 (0.94)	3.01 (0.96)	-0.52* (-0.40, -0.64)	2.74 (0.99)	2.94 (0.91)	-0.20* (-0.06, -0.34)
MAIA Attention regulation	2.53 (1.01)	3.37 (0.77)	-0.84* (-0.71, -0.97)	3.01 (0.87)	3.38 (0.77)	-0.42* (-0.29, -0.55)
MAIA Emotion awareness	3.55 (0.94)	3.99 (0.80)	-0.47* (-0.36, -0.58)	3.69 (0.93)	3.99 (0.75)	-0.32* (-0.20, -0.45)
MAIA Self-regulation	2.68 (1.12)	3.62 (0.82)	-0.83* (-0.70, -0.97)	3.23 (0.93)	3.74 (0.77)	-0.54* (-0.40, -0.69)
MAIA Body listening	2.17 (1.25)	3.13 (0.95)	-0.77* (-0.64, -0.89)	2.61 (1.18)	3.15 (0.95)	-0.45* (-0.32, -0.58)
MAIA Trusting	2.78 (1.26)	3.65 (1.01)	-0.69* (-0.56, -0.81)	3.12 (1.22)	3.59 (1.03)	-0.39* (-0.26, -0.52)
MAIA Body awareness	2.77 (0.77)	3.46 (0.64)	-0.90* (-0.77, -1.02)	3.10 (0.74)	3.47 (0.64)	-0.49* (-0.37, -0.61)
SCS Self-kindness	2.92 (1.03)	3.69 (0.89)	-0.75* (-0.62, -0.87)	3.01 (0.95)	3.85 (0.85)	-0.88* (-0.70, -1.05)
SCS Common humanity	3.00 (0.96)	3.38 (1.11)	-0.40* (-0.28, -0.52)	3.00 (0.96)	3.72 (0.92)	-0.75* (-0.58, -0.93)

SCS Mindfulness	3.24 (0.95)	3.81 (0.81)	-0.60* (-0.47, -0.72)	3.40 (0.90)	3.91 (0.72)	-0.57* (-0.41, -0.73)
SCS Self-compassion	2.98 (0.82)	3.73 (0.96)	-0.92* (-0.79, -1.05)	3.10 (0.83)	3.87 (0.70)	-0.93* (-0.76, -1.09)
IRI Empathic Concern	28.48 (4.05)	28.65 (4.08)	-0.04 (0.06, -0.15)	28.05 (3.86)	29.15 (4.08)	-0.28* (-0.12, -0.45)
DASS Stress	7.94 (3.99)	5.45 (3.73)	0.62* (0.76, 0.48)	6.86 (4.01)	4.95 (3.16)	0.47* (0.63, 0.32)
DASS Depression	4.53 (4.52)	2.59 (3.18)	0.43* (0.54, 0.32)	4.08 (4.30)	2.28 (3.12)	0.42* (0.58, 0.25)
DASS Anxiety	3.55 (3.32)	2.69 (2.58)	0.26* (0.37, 0.14)	3.09 (3.44)	2.14 (2.10)	0.27* (0.42, 0.13)
RRS Brooding	9.68 (3.08)	8.34 (2.45)	0.44* (0.56, 0.32)	9.05 (2.80)	8.09 (2.38)	0.34* (0.48, 0.20)
RRS Reflection	10.80 (3.05)	10.56 (3.08)	0.08 (0.19, -0.03)	10.60 (2.88)	9.96 (2.84)	0.22* (0.35, 0.09)
RRS Rumination total	20.48 (5.11)	18.90 (4.49)	0.31* (0.43, 0.19)	19.65 (4.62)	18.05 (4.34)	0.34* (0.48, 0.20)
WBSI Thought suppression	32.34 (7.88)	28.49 (8.20)	0.49* (0.59, 0.38)	30.88 (8.10)	27.94 (8.36)	0.36* (0.47, 0.25)
SWLS Life Satisfaction	22.84 (6.46)	24.57 (6.15)	-0.27* (-0.18, -0.36)	23.86 (5.90)	24.94 (5.78)	-0.18* (-0.07, -0.30)
PHI General well-being	13.40 (3.89)	14.73 (3.61)	-0.34* (-0.24, -0.44)	14.03 (3.60)	15.18 (3.29)	-0.32* (-0.19, -0.44)
PHI Eudaimonic well-being	44.74 (9.67)	48.60 (8.81)	-0.40* (-0.30, -0.50)	45.88 (9.50)	49.27 (8.23)	-0.36* (-0.22, -0.49)
PHI Hedonic well-being	13.58 (4.31)	15.33 (3.57)	-0.40* (-0.31, -0.50)	14.60 (4.03)	15.86 (3.67)	-0.31* (-0.18, -0.44)
PHI Social well-being	5.45 (2.48)	6.32 (2.55)	-0.35* (-0.24, -0.45)	6.06 (2.46)	6.48 (2.41)	-0.17* (-0.05, -0.28)
PHI Well-being total	77.18 (17.74)	84.98 (16.24)	-0.44* (-0.34, -0.53)	80.58 (16.97)	86.79 (15.15)	-0.36* (-0.14, -0.59)

MBSR: Mindfulness-Based Stress Reduction; CCT: Compassion Cultivation Training; M: mean; SD: standard deviation; d: Cohen's d; CI: Confidence Interval.
*: significant effect size based on the confidence intervals. Description of the variables and their acronyms is shown in Table 1.

Supplementary Table 2. Simple mediation of the effects of MBSR vs CCT on post-pre changes in psychological distress (i.e., stress, anxiety and depression) and well-being, mediated by its action mechanisms (post-pre scores) and controlled for baseline levels of outcomes and mediators (pre scores).

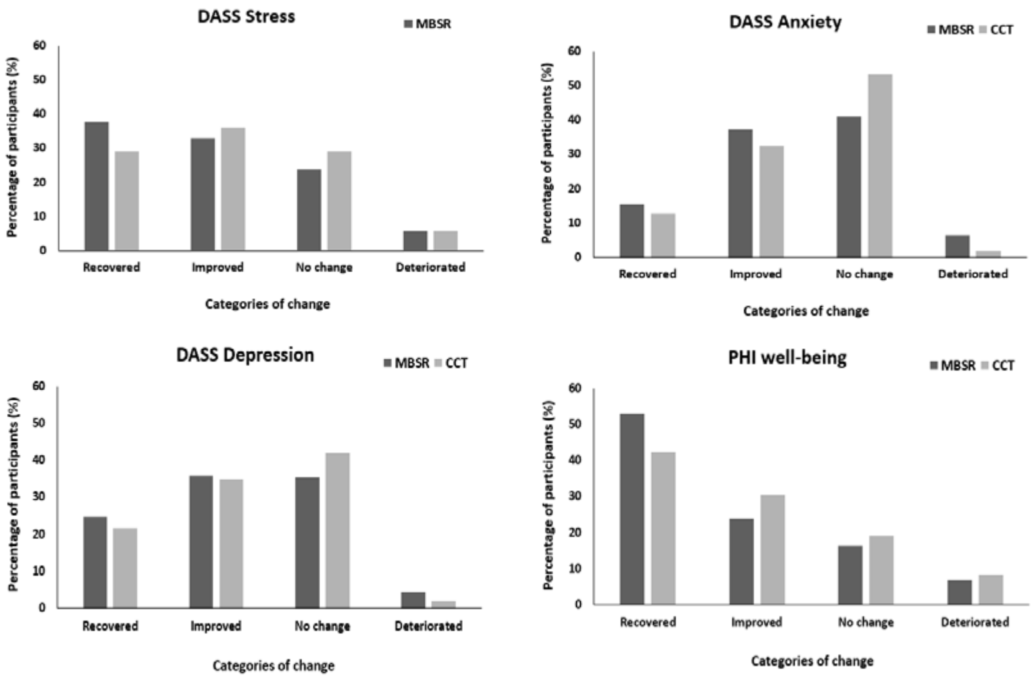
Mediators	**Path a** **b (s.e.)**	**Path b** **b (s.e.)**	**Path c** **b (s.e.)**	**Path c'** **b (s.e.)**	**Indirect effect** ***ab* (s.e.) [95% CI]**	***R*²**
DASS Stress						
FFMQ Observing	-0.05 (0.05)	-2.01 (0.04)***	-0.01 (0.04)	-0.02 (0.04)	0.01 (0.01) [-0.01, 0.03]	-
FFMQ Mindfulness Total	-0.04 (0.04)	-0.49 (0.05)***	0.01 (0.04)	-0.01 (0.04)	0.02 (0.02) [-0.03, 0.05]	-
EQ Decentering	-0.12 (0.04)*	-0.46 (0.04)***	-0.01 (0.04)	-0.06 (0.04)	**0.05 (0.02) [0.01, 0.09]***	0.56*
MAIA Noticing	-0.18 (0.06)*	-0.13 (0.03)***	-0.01 (0.04)	-0.03 (0.04)	**0.02 (0.01) [0.01, 0.05]***	0.46*
MAIA Not-Worrying	-0.22 (0.08)**	-0.12 (0.03)***	-0.01 (0.04)	-0.04 (0.04)	**0.03 (0.01) [0.01, 0.05]***	0.56*
MAIA Attention Regulation	.0.25 (0.06)***	-0.22 (0.03)***	-0.00 (0.04)	-0.06 (0.04)	**0.05 (0.01) [0.03, 0.08]***	0.49*
MAIA Self-Regulation	-0.13 (0.07)*	-0.26 (0.03)***	-0.01 (0.04)	-0.05 (0.04)	**0.03 (0.02) [0.01, 0.07]***	0.52*
MAIA Body Listening	-0.21 (0.08)**	-0.10 (0.03)***	-0.01 (0.04)	-0.03 (0.04)	**0.02 (0.01) [0.01, 0.04]***	0.45*
MAIA Trusting	-0.24 (0.08)*	-0.14 (0.02)***	-0.01 (0.04)	-0.05 (0.04)	**0.03 (0.01) [0.01, 0.07]***	0.47*
MAIA Total	-0.21 (0.04)***	-0.34 (0.04)***	-0.00 (0.04)	-0.07 (0.04)	**0.07 (0.02) [0.04, 0.11]***	0.51*
SCS Common Humanity	0.32 (0.10)**	-0.08 (0.02)***	-0.02 (0.04)	0.01 (0.04)	**-0.03 (0.01) [-0.05, -0.01]***	0.45*
IRI Empathic Concern	0.73 (0.31)*	-0.00 (0.01)	-0.02 (0.04)	-0.01 (0.04)	-0.00 (0.01 [-0.01, 0.01]	-
DASS anxiety						
FFMQ Observing	-0.06 (0.05)	-0.13 (0.03)***	-0.04 (0.03)	-0.05 (0.03)	0.01 (0.01) [-0.01, 0.02]	-
FFMQ Mindfulness Total	-0.03 (0.04)	-0.29 (0.04)***	-0.03 (0.03)	-0.04 (0.03)	0.01 (0.01) [-0.01, 0.03]	-
EQ Decentering	-0.11 (0.04)*	-0.20 (0.03)***	-0.03 (0.03)	-0.06 (0.03)	**0.02 (0.01) [0.01, 0.04]***	0.48*

MAIA Noticing	-0.18 (0.06)**	-0.02 (0.02)	-0.05 (0.03)	-0.05 (0.03)	0.00 (0.01) [-0.01, 0.02]	-
MAIA Not-Worrying	-0.20 (0.08)*	-0.07 (0.02)**	-0.04 (0.03)	-0.06 (0.03)	**0.01 (0.01) [0.01, 0.03]***	0.48*
MAIA Attention Regulation	-0.25 (0.06)***	-0.11 (0.02)***	-0.04 (0.03)	-0.07 (0.03)*	**0.03 (0.01) [0.01, 0.05]***	0.47*
MAIA Self-Regulation	-0.12 (0.07)	-0.14 (0.02)***	-0.05 (0.03)	-0.06 (0.03)*	0.02 (0.01) [-0.00, 0.03]	-
MAIA Body Listening	-0.22 (0.08)**	-0.04 (0.02)	-0.05 (0.03)	-0.06 (0.03)	0.01 (0.01) [-0.00, 0.02]	-
MAIA Trusting	-0.24 (0.08)**	-0.08 (0.02)***	-0.04 (0.03)	-0.06 (0.03)*	**0.02 (0.01) [0.01, 0.04]***	0.49*
MAIA Total	-0.21 (0.05)***	-0.17 (0.03)***	-0.04 (0.03)	-0.07 (0.03)*	**0.04 (0.01) [0.02, 0.06]***	0.48*
SCS Common Humanity	0.34 (0.10)**	-0.05 (0.15)**	-0.05 (0.03)	-0.03 (0.03)	**-0.02 (0.01) [-0.03, -0.0.1]***	0.47*
IRI Empathic Concern	0.89 (0.30)**	0.00 (0.00)	-0.05 (0.03)	-0.06 (0.03)	0.00 (0.00) [-0.01, 0.01]	-
DASS Depression						
FFMQ Observing	-0.05 (0.05)	-0.13 (0.03)**	0.01 (0.04)	-0.00 (0.03)	0.01 (0.01) [-0.01, 0.02]	-
FFMQ Mindfulness Total	-0.03 (0.04)	-0.36 (0.05)***	-0.00 (0.04)	-0.01 (0.03)	0.01 (0.01) [-0.01, 0.04]	-
EQ Decentering	-.10 (0.44)*	-0.33 (0.04)***	-0.01 (0.04)	-0.04 (0.03)	**0.03 (0.01) [0.01, 0.06]***	0.56*
MAIA Noticing	-0.17 (0.06)**	-0.06 (0.03)*	0.00 (0.04)	-0.01 (0.04)	0.01 (0.01) [0.00, 0.03]	-
MAIA Not-Worrying	-0.20 (0.08)*	-0.08 (0.02)**	-0.02 (0.04)	-0.03 (0.04)	0.02 (0.01) [-0.11, 0.04]	-
MAIA Attention Regulation	-0.25 (0.06)***	-0.14 (0.03)***	-0.00 (0.04)	-0.04 (0.04)	**0.03 (0.01) [0.02, 0.06]***	0.52*
MAIA Self-Regulation	-0.13 (0.07)*	-0.19 (0.03)***	-0.00 (0.04)	-0.03 (0.03)	0.03 (0.01) [0.00, 0.05]	-
MAIA Body Listening	-0.21 (0.07)**	-0.09 (0.02)**	-0.00 (0.04)	-0.02 (0.04)	0.02 (0.01) [0.00, 0.04]	-
MAIA Trusting	-0.24 (0.08)**	-0.14 (0.02)***	-0.01 (0.04)	-0.04 (0.04)	**0.03 (0.01) [0.01, 0.06]***	0.53*
MAIA Total	-0.21 (0.05)***	-0.25 (0.04)***	0.01 (0.04)	-0.04 (0.04)	**0.05 (0.01) [0.03, 0.08]***	0.52*
SCS Common Humanity	0.34 (0.10)**	-0.09 (0.02)***	-0.01 (0.04)	0.02 (0.04)	**-0.03 (0.01) [-0.05, -0.01]***	0.50*
IRI Empathic Concern	0.81 (0.30)	-0.01 (0.01)	-0.02 (0.04)	-0.01 (0.04)	.0.01 (0.01) [-0.02, 0.01]	-

PHI well-being						
FFMQ Observing	-0.05 (0.05)	5.64 (0.92)***	-0.85 (1.01)	-0.57 (0.97)	-0.28 (0.30) [-0.90, 0.30]	-
FFMQ Mindfulness Total	-0.03 (0.04)	14.00 (1.28)***	-044 (1.05)	-0.07 (0.93)	-0.37 (0.49) [-1.37, 0.58]	-
EQ Decentering	-0.11 (0.04)*	11.28 (0.99)***	-0.79 (0.99)	0.44 (0.87)	**-1.23 (0.48) [-2.19, -0.33]***	0.42*
MAIA Noticing	-0.17 (0.06)**	4.85 (0.74)***	-0.98 (1.00)	-0.18 (0.96)	**-0.81 (0.30) [-1.43, -0.24]***	0.34*
MAIA Not-Worrying	-0.22 (0.08)**	3.35 (0.65)***	-0.70 (1.06)	0.03 (1.03)	**-0.73 (0.29) [-1.34, -0.22]***	0.29*
MAIA Attention Regulation	-0.25 (0.06)***	5.33 (0.80)***	-1.08 (1.02)	0.27 (0.99)	**-1.34 (0.37) [-2.12, -0.68]***	0.33*
MAIA Self-Regulation	-0.12 (0.06)	6.39 (0.72)***	-0.82 (1.02)	-0.06 (0.94)	-0.76 (0.41) [-1.59, 0.04]	-
MAIA Body Listening	-0.21 (0.07)**	3.64 (0.67)***	-0.47 (1.08)	0.29 (1.05)	**-0.75 (0.32) [-1.45, -0.22]***	0.27*
MAIA Trusting	-0.25 (0.08)**	3.91 (0.59)***	-0.84 (1.00)	0.16 (0.96)	**-1.00 (0.34) [-1.71, -0.38]***	0.33*
MAIA Total	-0.20 (0.04)***	9.64 (1.00)***	-0.98 (1.01)	0.98 (0.94)	**-1.96 (0.45) [-2.88, -1.12]***	0.39*
SCS Common Humanity	0.31 (0.10)**	2.66 (0.49)***	-0.89 (1.00)	-1.73 (0.98)	**0.84 (0.28) [0.34, 1.44]***	0.31*
IRI Empathic Concern	0.79 (0.31)*	0.45 (0.17)**	-0.56 (1.06)	-0.91 (1.06)	**0.35 (0.23) [0.02, 0.91]***	0.25*

b = unstandardized regression coefficients; *s.e.* = standard error; 95% CI = Confidence Interval.
Values marked in bold indicate significant indirect effect based on the 95% Confidence Intervals (zero not included in the interval).
* $p < .05$; ** $p < .01$; and *** $p < .001$

Supplementary Figure 1. Reliable Change Index for outcomes measures. MBSR = Mindfulness-Based Stress Reduction; CCT = Compassion Cultivation Training.



SUPLEMENTARY MATERIALS – MBSR NETWORK

Does mindfulness change the mind?
A novel *psychonectome* perspective based on Network Analysis

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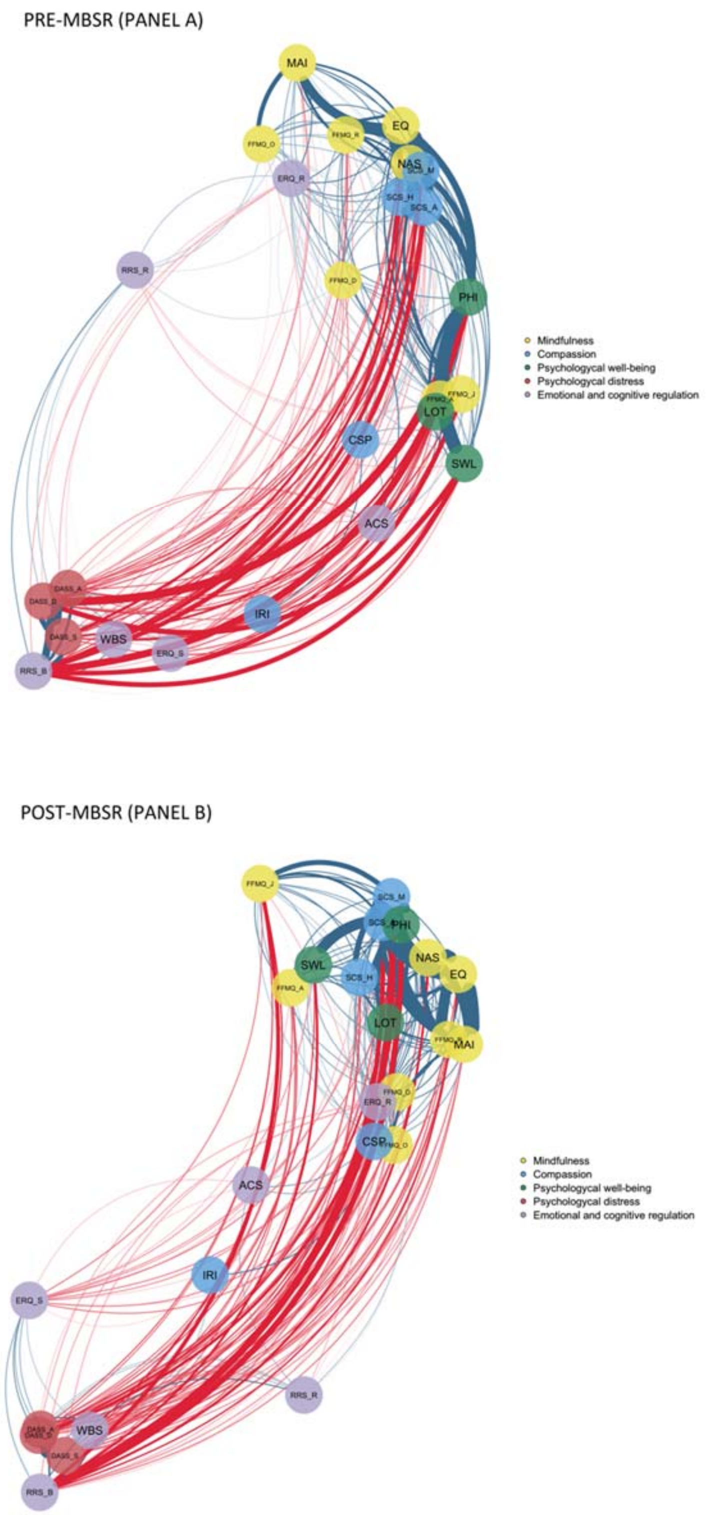
Supplementary Methods and Results

1. Network estimation

In networks plotted with traditional force-directed algorithms the spatial nodes allocation is not directly interpretable. For this reason, other plotting approaches have been suggested in order to improve the visual interpretation of the networks [1]. Considering that factor/clusters are used in the networks of the present study, it would be a good alternative to use Principal Components Analysis algorithm (PCA) to visualize the networks using the *psych* R-package [2]. The main advantage of PCA plotting is that the spatial placement of nodes on the X and Y axes becomes interpretable. For instance, nodes placed far to the right X axis differ in some dimension from the nodes placed on the left side. Furthermore, PCA is specifically applied to psychometric networks based on a correlation matrix (as it is the case of the present study).

A visual inspection of the plot of our data using PCA method (see Supplementary Figure 1), seems to simply reflect two factors: one with psychopathology-related domains (e.g., psychological distress and emotion dysregulation) and the other with the rest of domains (i.e., mindfulness, compassion and well-being). Yet, given that the theoretical framework of our study considered five distinct domains of variables, the two PCA axes should be interpreted with caution.

Supplementary Figure 1. Principal Components Analysis Network configurations of Pre- (panel A) and Post-MBSR intervention (panel B). Blue edges represent positive relationships and red lines represent negative ones.

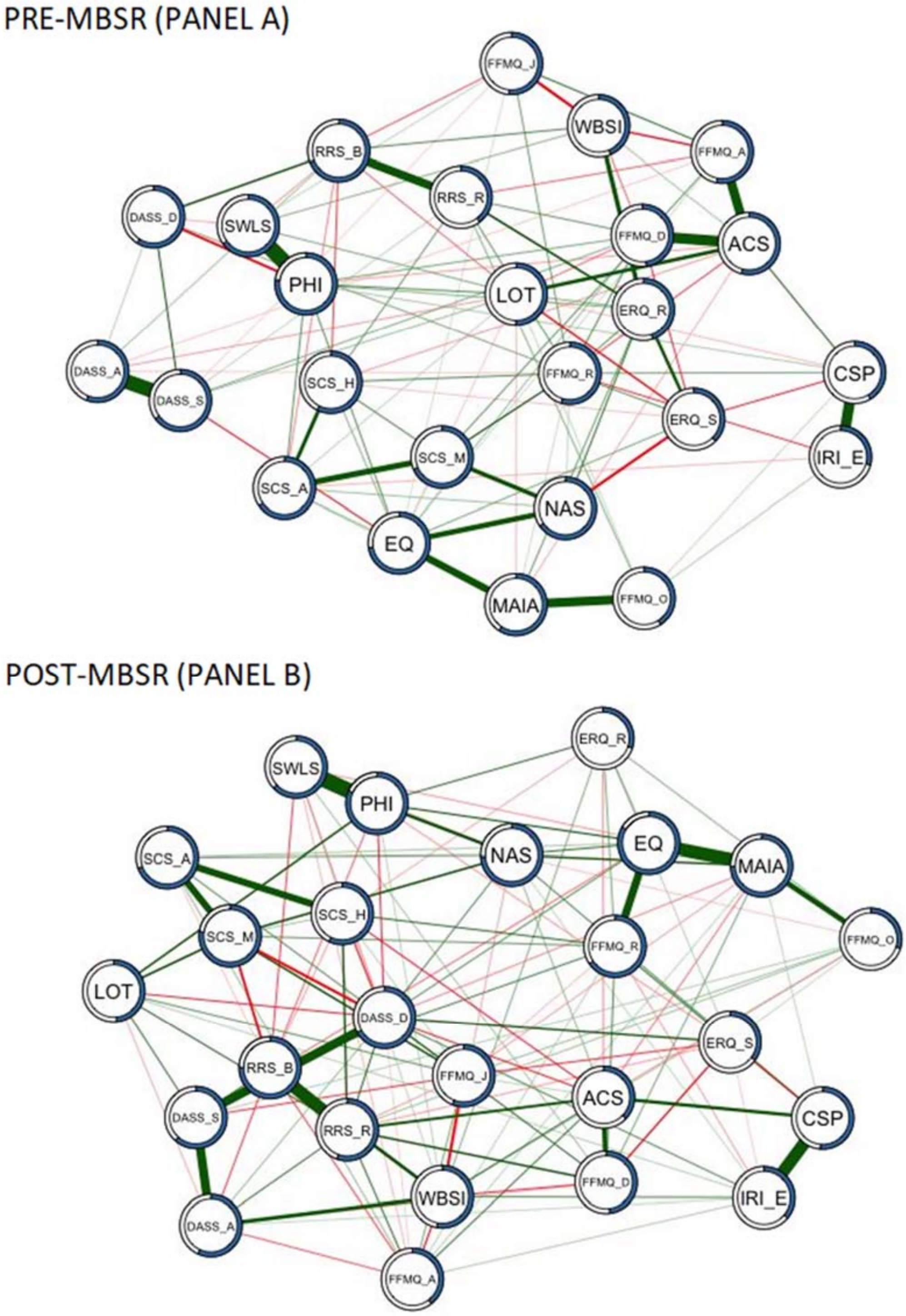


2. Network inference

Aiming to test whether the topological reorganization was made by means of changing the number of connections, their strength, or both, the correlation between degree and strength among all constructs was estimated. The correlation between degree and strength was statistically significant in both pre-intervention and post-intervention networks [R = 0.68 (p = 0.0002) and R=0.64 (p=0.0004), respectively), which means that the networks linearly reorganized both the number of connections and their weights. This result excludes the possibility that dependences were artificially increased by reducing the interaction weights between variables or the possibility that strength would change while keeping intact the topology, in whose case no topological reorganization would have occurred. In order to study the reorganization complexity, clustering and efficiency correlation analyses were performed. These analyses showed a significant correlation before the MBSR (R = 0.62, p = 0.009) but not after (R = 0.19, p = 0.36). The lack of correlation after the program seems to support a structural reorganization of the network.

3. Network predictability

Supplementary Figure 2. Pre- (panel A) and Post-MBSR intervention (panel B) predictability. The blue ring around each node represents the percentage of variance predicted by all the nodes that are connected to it. Positive relationships are represented with green edges and negative relationships are represented with red ones.



Supplementary Figure 3. Pre- and Post-MBSR intervention predictability scores (i.e., percentage of variance for each node of the network).

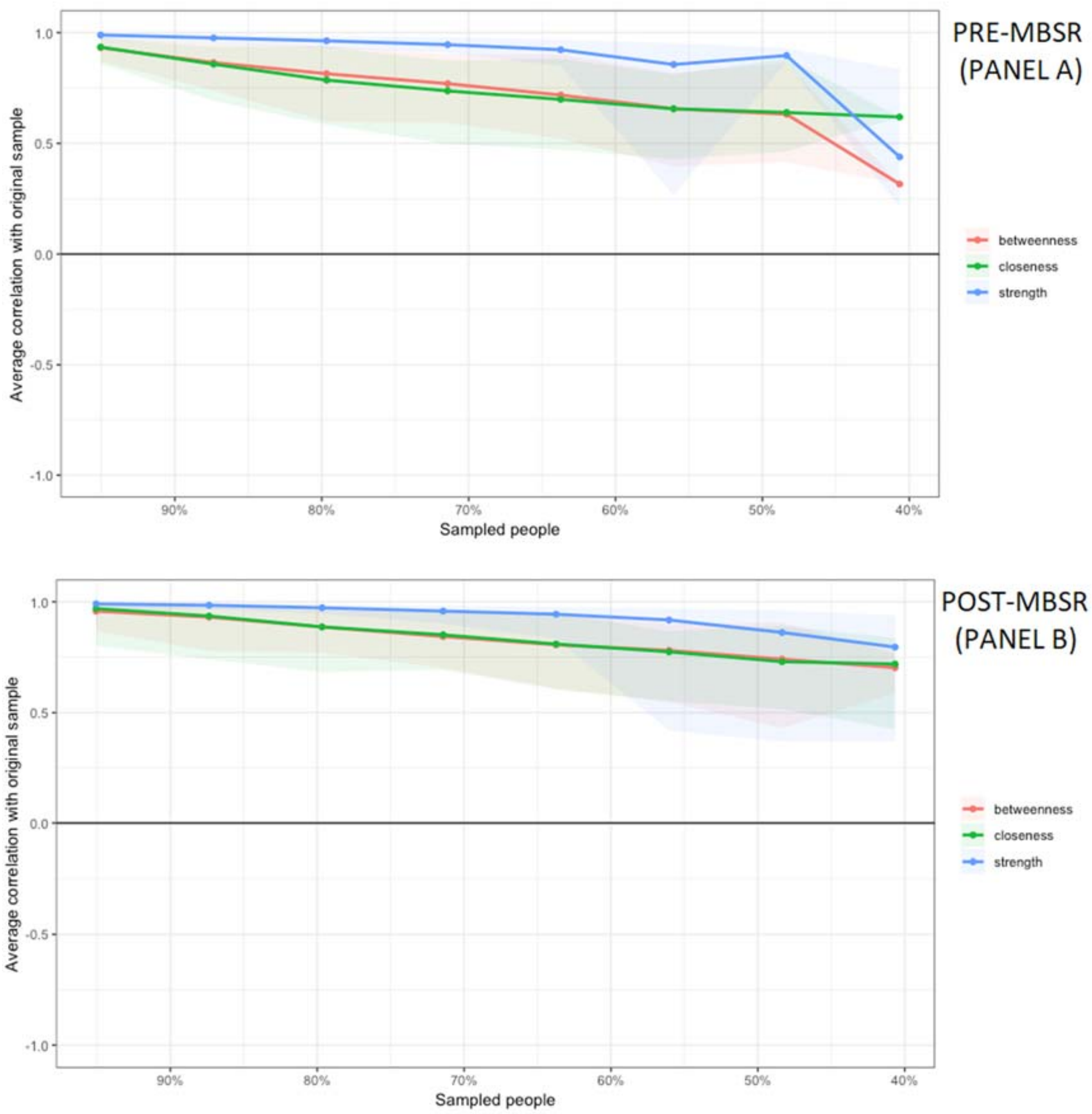
4. Network stability

We analyzed the accuracy (i.e. resistance to sampling variation) and stability (i.e. whether the network interpretation remains stable with less observation) of the networks using R-package *bootnet* [3]. We used the following measures: a) accuracy of edges estimation, by constructing a 95% Confidence Interval (CI) around each edge-weights of the network: the smaller the CIs the more accurately the network is estimated; and b) stability of centrality indices, estimated via the Centrality-Stability Coefficient (CS-coefficient). The CS-coefficient represents the proportion of participants that can be dropped from the analysis, while maintaining a very large correlation with the original centrality indices. The CS-coefficient ranges from 0 to 1 (larger values indicate higher stability): simulation studies have found that values above 0.25 show moderate stability and above 0.5 strong stability [4]. We computed all the indices for each network (pre- and post-MBSR).

Supplementary Figure 4 shows the bootstrapped 95% CI around each edge-weight. Stability analyses indicated that pre- and post-MBSR networks were accurately estimated, with small to moderate CIs around the edge-weights.

Supplementary Figure 5 shows the stability of centrality indices. Although all of them showed high stability along the bootstrapped samples (i.e. drops in stability were very small), strength showed more stability than closeness and betweenness. The CS-coefficient indicates that strength centrality was moderately stable at pre-MBSR (CS = 0.36) and close to high at post-MBSR (CS = 0.44). Both betweenness (CS=0.13) and closeness (CS = 0.13) at pre-MBSR showed low stability, although both achieved moderate stability levels at post-MBSR ($CS_{betweenness}$ = 0.29 and $CS_{closeness}$ = 0.29).

Supplementary Figure 5. Pre-MBSR (Panel A) and post- MBSR (Panel B) stability of centrality indices, showing an average correlation between the centrality indices of the original sample with people dropped. The y-axis represents the percentage of people dropped in the bootstrapped samples. The blue, red and green lines indicate the centrality index mean and the areas indicate the range from the 2.5th quantile to the 97.5th quantile.



Supplementary Figure 4. 95% bootstrapped CIs around each edge-weight for the estimated networks of pre-MBSR (left) and post- MBSR (right). The red line indicates the sample values, the black line indicates the bootstrap mean and the gray area represents the bootstrapped CIs. The y-axis labels represent all network edges, ordered from the edge with the highest weight (up) to the edge with the lowest weight (down).

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SUPLEMENTARY MATERIALS – CCT NETWORK

The impact of compassion meditation training on psychological variables: A network perspective

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Supplementary Methods and Results

Statistical Analyses

Network analysis was conducted following successive steps (Fried et al., 2018; Jones et al., 2019):

2. Pre- and post-CCT network estimation. A Gaussian Graphical Model (GGM) (Lauritzen, 1996) was used to estimate the pre- and post-CCT networks structure, estimating Regularized Partial Correlation Networks (RPC) with the connections between the 25 psychological constructs (see Table 1 in main manuscript), selected to analyze the psychological impact of compassion training (see Table 2 in main manuscript). Spearman correlation matrix was used as input for the GGM (for a recent tutorial, see Epskamp et al., 2018). The RPC Networks are based on two features: (a) the association between two nodes indicates that this relation remains conditionally dependent after controlling for all other associations among the rest nodes in the network; and (b) the regularization strategy uses LASSO correction to shrink connections in the network by setting small connections to zero. This strategy reduces the number of false positive correlations within networks and avoids spurious connections between nodes, which facilitates the network structure interpretation (S. Epskamp & Fried, 2018). The q-graph R-package (Epskamp et al., 2012) was used to visualize the networks, using the Parcor R-package (Krämer et al., 2009) to implement the adaptive LASSO approach and the Fruchterman-Reingold algorithm (Fruchterman & Reingold, 1991) to draw close together nodes with high centrality (i.e. stronger connections or more number of connections) and putting in the periphery nodes with low centrality. Taking into account that the CCT networks would include constructs from 5 different domains, Principal Components Analysis algorithm (PCA) was used as an alternative network visualization (Jones et al., 2018), using psych R-package (Revelle, 2017). In contrast to traditional force-directed algorithms, the main advantage of PCA is that the spatial nodes allocation is directly interpretable.

3. Pre- and post-CCT network inference. The potential importance of each psychological construct (i.e. nodes) within the CCT networks was calculated using centrality indexes. Centrality measures represent the connections of a node with all other nodes in the network, under the assumption that highly connected nodes are usually more relevant in the network. Given that negative relations between nodes were expected in the CCT networks (e.g., mindfulness, compassion and well-being with psychological distress), node's Expected Influence index (EI) (Robinaugh et al., 2016) was estimated as a complement to node's strength, using expectedinf function from the networktools R-package (Jones, 2017). While strength is the sum of the absolute weights connected to each node, EI takes into account both positive and negative weights between nodes which allows a more direct interpretability of centrality. Furthermore, considering the low reliability of some centrality indexes (e.g., betweenness and closeness) (Bringmann et al., 2018; Lü et al., 2016), clustering centrality was included to measure how close a node is to the other network nodes by sharing a clustering (i.e., high clustering means that a node's neighbors are also neighbors between them). Furthermore, the Network Comparison Test (NCT; van Borkulo et al., 2017) was carried out to test whether the overall network connectivity significantly differed between pre- and post-CCT networks, by using the R package NCT (van Borkulo et al., 2017). The NCT is a two-tailed permutation test (i.e., bootstrapping samples), comparing the invariance across the subpopulations in: (1) the strength of each edge and node in the network; (2) the overall network structure; and (3) the global network strength (i.e., the sum of absolute connections within a network) and the global network expected influence (i.e., the sum of positive and negative connections within a network). In contrast with psychopathology networks, where it is hypothesized that the networks with strong connections between symptom would be more pathogenic than network with weak connections (Borsboom, 2017), from the 'psychonectome perspective' (Roca et al., 2019), which conceptually allows the inclusion of adaptive and pathological nodes in the same network, it was expected that some connections would increase their strength while others would reduce it.

4. Pre- and post-CCT nodes predictability. Whereas centrality measures are relative measures of interconnectedness, predictability is an absolute measure of interconnectedness. Predictability is defined as the degree to which a given node can be "predicted" by all other nodes in the network (i.e., how much variance of a node can be explained by other nodes in the network). Predictability was estimated using the mgm R package (Haslbeck & Fried, 2017).

5. Pre- and post-CCT network node communities. The community structure was explored to analyze the CCT reorganization after the program using igraph R package (Csárdi & Nepusz, 2006) with the Spinglass algorithm (Reichardt & Bornholdt, 2006). A community is defined as a set of nodes that clusters more strongly amongst each other than with other nodes of the network, resulting in small families or cluster within the network. The communities that appeared after the CCT program would be a result of increased mutual influences among some nodes in a given cluster. The following parameters were used (Maccallum et al., 2017): $\gamma = 1$; start temperature = 1; stop temperature = .01; cooling factor = .99; spins = 25.

a. Spinglass and walk-trap algorithms are the most trustworthy methods for community detection. Both yield similar results (Briganti et al., 2018; Jones et al., 2018). We used the spinglass algorithm to enable direct comparison to Roca et al. (2019) study

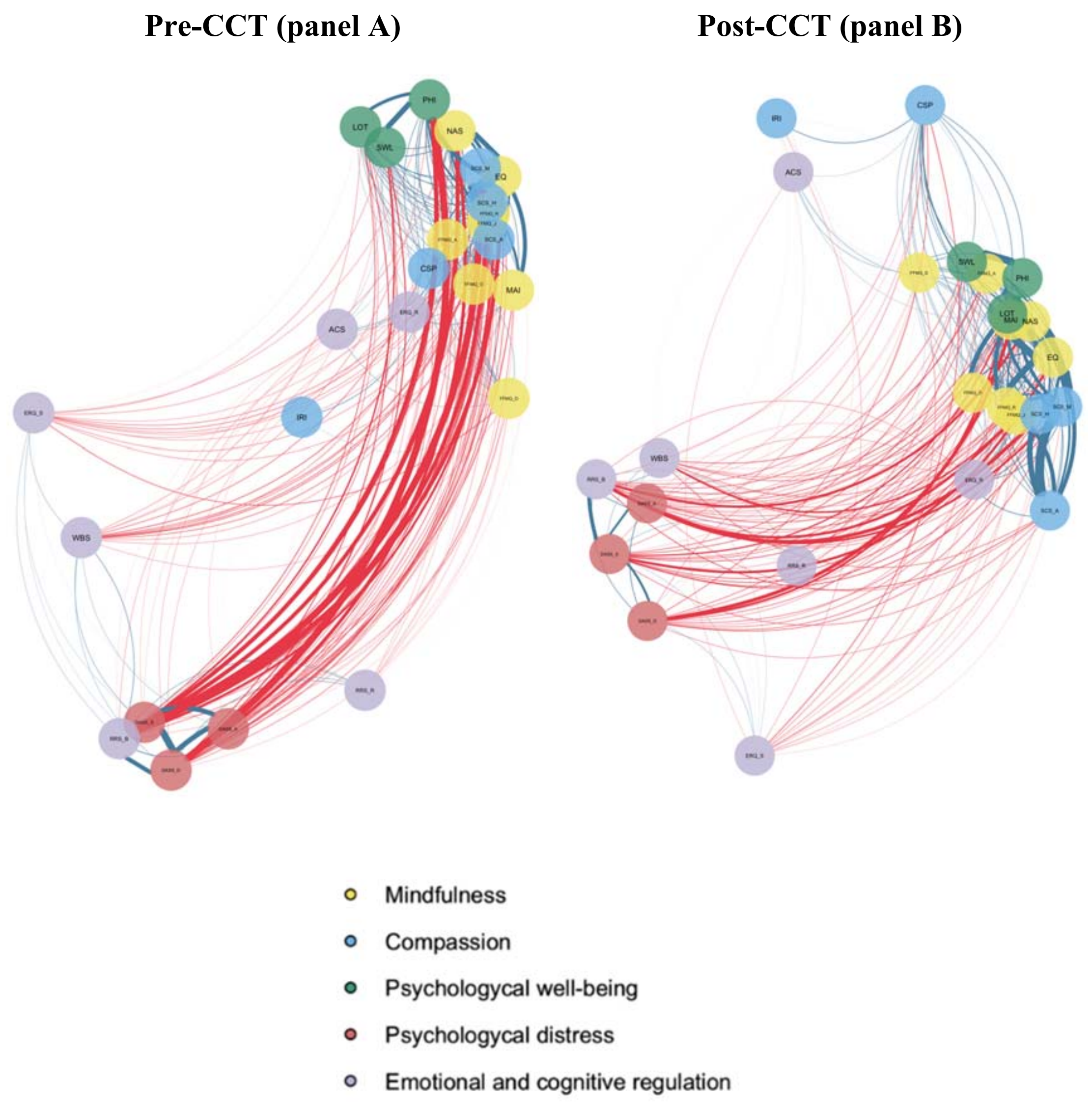
6. Pre- and post-CCT bridge centrality. Additionally, we used bridge centrality analysis (Jones et al., 2019) to identify important nodes connect theoretically important subnetworks (i.e., mindfulness, compassion, well-being, psychological distress and emotional/cognitive control). To clarify the association among different set of measures, we calculated one-step bridge expected influence (EI1) (i.e., the sum of edge weights connecting a given node to all nodes in other subnetworks). An 80% cut-off identified the nodes with the highest bridge EI in pre- and post-CCT networks. To compute bridge centrality, we used the bridge function from the R package *networktools* (Jones, 2017).

7. Pre- and post-CCT network's robustness (accuracy and stability). The network resistance to sampling variations (i.e. accuracy) and whether the network interpretation remains stable with less observations (i.e. stability) were calculated by using the *bootnet* R-package (Epskamp et al., 2018). The following measures were computed for pre- and post-CCT network: (1) Accuracy of edges estimation: by constructing a 95% Confidence Interval (CI) around each edge of the network by using a non-parametric bootstrapping, assuming that the smaller CIs around the edge the more accurately is estimated; and (2) Centrality-Stability Coefficient (CS-coefficient): to estimate the stability of centrality indices. The CS-coefficient represents the maximum percentage of participants that can be dropped from the analysis while maintaining a large correlation with the original centrality indices (r = 0.7). The CS-coefficient ranges from 0 to 1 and large values indicate higher node centrality stability. Simulation studies have found that values above 0.25 show moderate stability and above 0.5 strong stability (Fried et al., 2018).

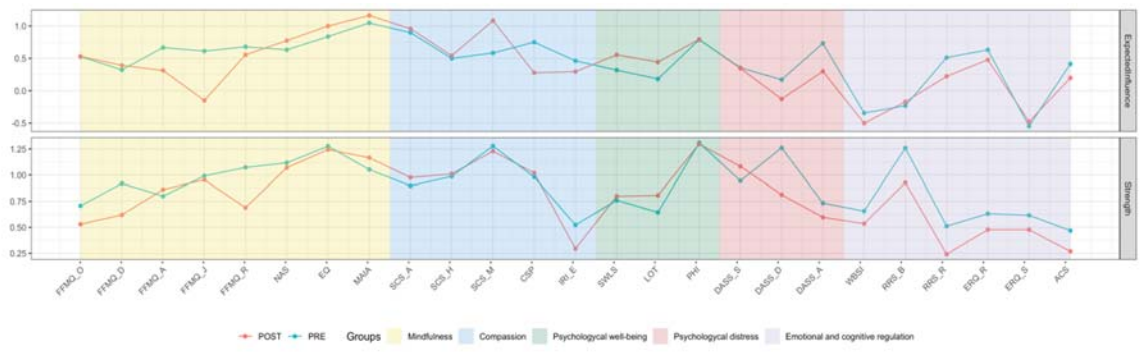
Results

2. Pre- and post-CCT network estimation

Principal Components Analysis algorithm (PCA) was used as a plotting alternative to visualize the pre- and post-CCT networks (Supplementary Figure 1), where the spatial nodes allocation are directly interpretable. A visual inspection of the PCA network before the CCT program seems to reflect two main factors: one at the top of the Y-axis including adaptive variables (i.e., mindfulness, compassion, well-being and cognitive control) and the other factor at the bottom of the Y-axis including psychopathology-related domains (e.g., psychological distress and cognitive/emotional dysregulation). The emotional suppression construct (ERQ-S) is placed in an equidistant position from both factors. The PCA network after the CCT program also showed the two-factor configuration, but compassion to others (CSP), empathic concern (IRI-E) and attentional control (ACS) were separated from the adaptive variables. Yet, given that the theoretical framework of our study considered five different domains of psychological variables, the two PCA axes should be interpreted with caution.



Supplementary Figure 1. Principal Components Analysis network configuration before (panel A) and after (panel B) the CCT program. The networks are graphed by nodes (i.e. circles representing the psychological constructs described in Table 1) and edges (i.e. lines representing correlations between the different nodes). Blue edges represent positive relations and red lines represent negative ones. In contrast to traditional force-directed algorithms (i.e. Fruchterman-Reingold algorithm), the spatial nodes allocation is directly interpretable.



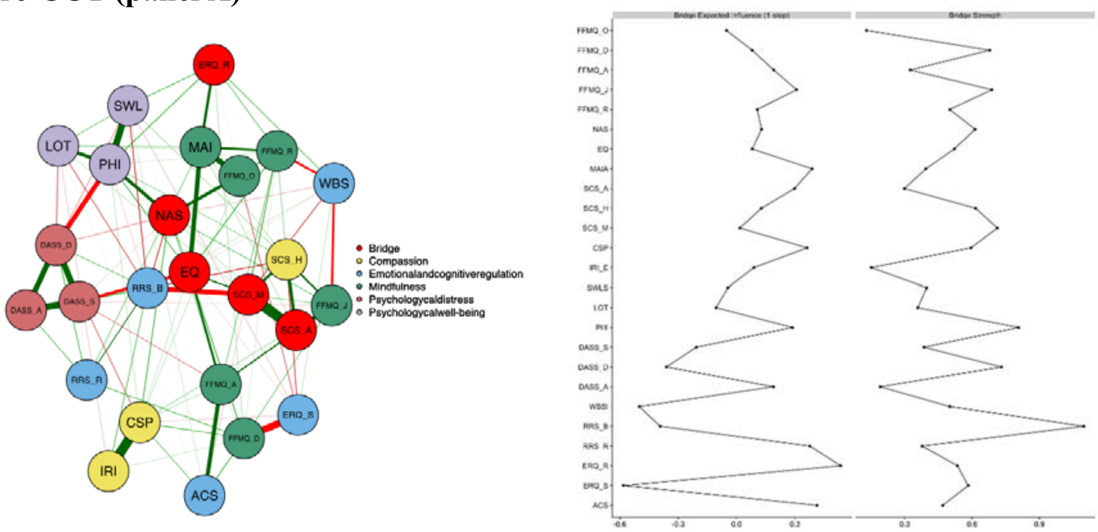
Supplementary Figure 2. Centrality measures for pre- and post-CCT networks (topological characterization). Each centrality measure estimates the topological role of each node in the network (x-axis), described in Table 1. Expected Influence: the sum of both positive and negative weights between a node and all other nodes in the network (nodes with high EI are strongly and positively associated with other nodes in the network). Strength: sum of the absolute weights of all edges in the network involving that node (nodes with high strength are strongly associated with other nodes in the network).

4. Pre- and post-CCT nodes predictability

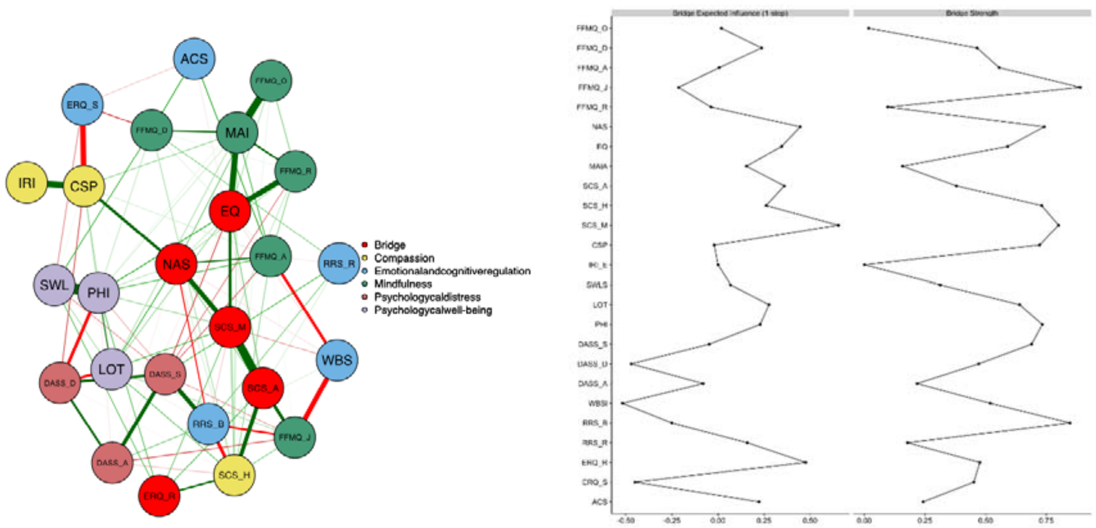
Supplementary Figure 3. Predictability scores before and after the CCT program. Predictability represents the percentage of variance for each node of the network.

6. Pre- and post-CCT bridge centrality

Pre-CCT (panel A)



Post-CCT (panel B)



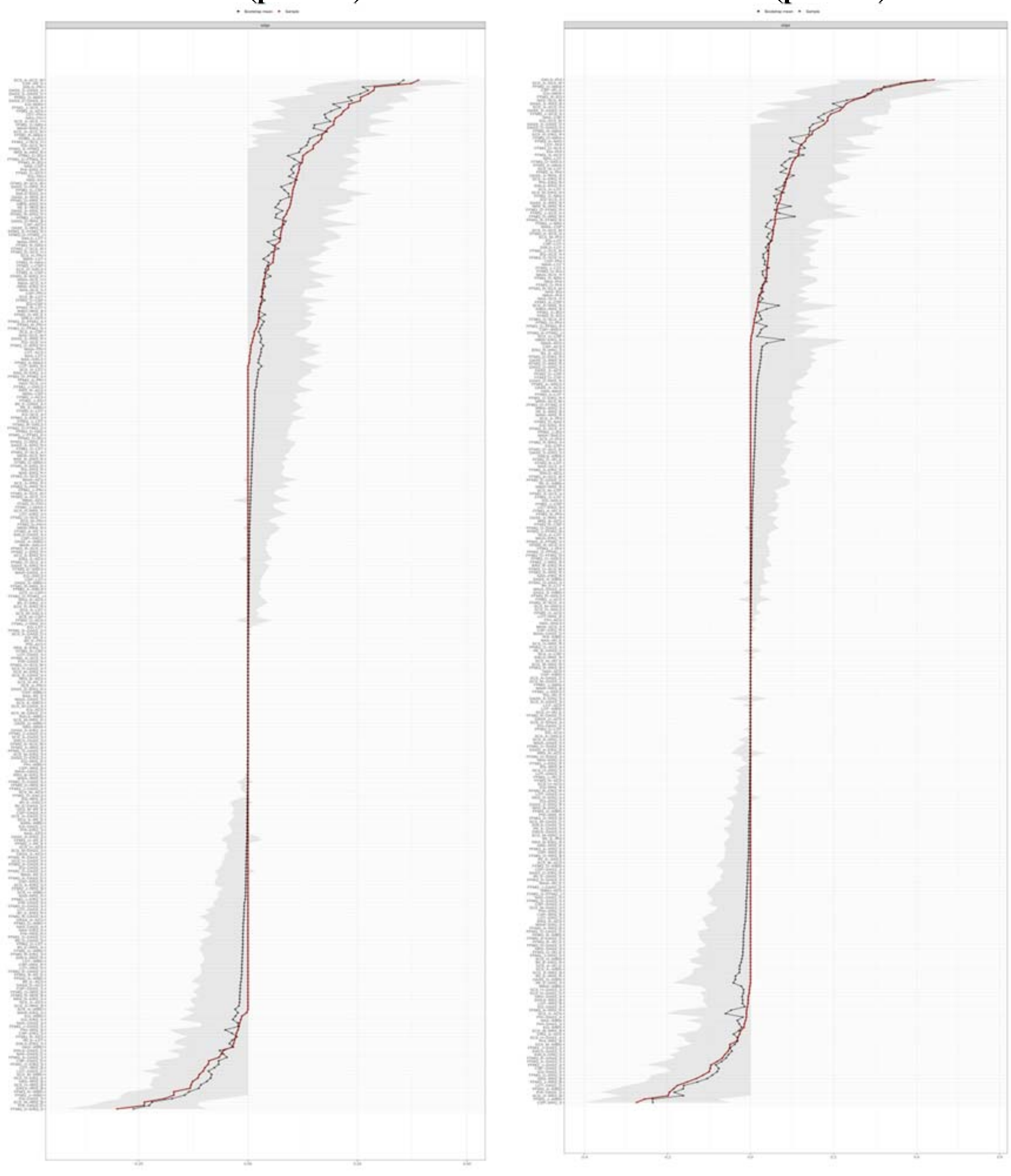
Supplementary Figure 4. GGM network highlighting subnetwork structure and most influential bridge nodes. Nodes with the highest bridge expected influence are depicted in red. Compassion measures are represented in yellow, mindfulness in green, well-being measures in purple, psychological distress in crimson and emotional/cognitive control measures in blue. Plot shows the bridge one-step expected influence and bridge strength metrics for the graphical LASSO network.

7. Pre- and post-CCT network s accuracy and stability

Stability analyses indicated that pre- and post-CCT networks were accurately estimated, with small to moderate CIs around the edge-weights (see Supplementary Figure 4). There were no differences between the edge-weights of the original estimated networks and the bootstrapped networks, since all the original sample edge weights (red line) lied into the bootstrapped 95% CIs (gray area). Thus, the estimated pre- and post-CCT networks seem to be reliable. The edges self-kindness – mindful self-compassion (SCS-A – SCS-M), compassion to others – empathic concern (CSP – IRI-E), life satisfaction – general well-being (SWLS - PHI), depression – anxiety (DASS-D – DASS-A), and stress – depression (DASS-S – DASS-D) were the strongest edges before the CCT program since their CIs around the edge were quite different from other CIs. After the CCT program, although self-compassion, compassion to others and well-being edges still had the strongest edges, psychopathology-related nodes lost edge- weight (DASS). Also, after the CCT intervention, mindfulness edges emerged as the strongest ones. In particular observing - interoceptive body awareness (FFMQ-O - MAIA), decentering – non-interoceptive body awareness (EQ - MAIA) and non-reactivity to inner experience – decentering (FFMQ-R - EQ).

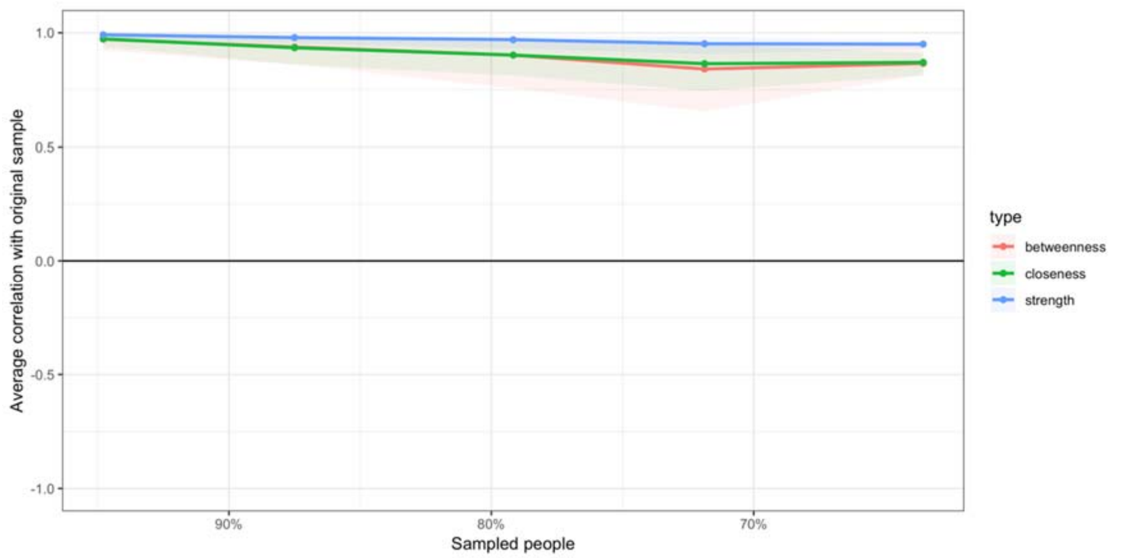
Furthermore, Supplementary Figure 5 shows that all the centrality indices showed a high stability along the bootstrapped samples before the CCT program (i.e. drops in stability were very small in the successive bootstrapped samples). After the CCT program, the stability is reduced from 80% of sampled dropped. The CS-coefficient indicated that strength centrality had low reliability both before (CS_{pre} =.094) and after (CS_{post} =.021) the CCT program. Therefore, the inferences drawn from centrality analyses should be interpreted cautiously.

Pre-CCT (panel A) **Post-CCT (panel B)**

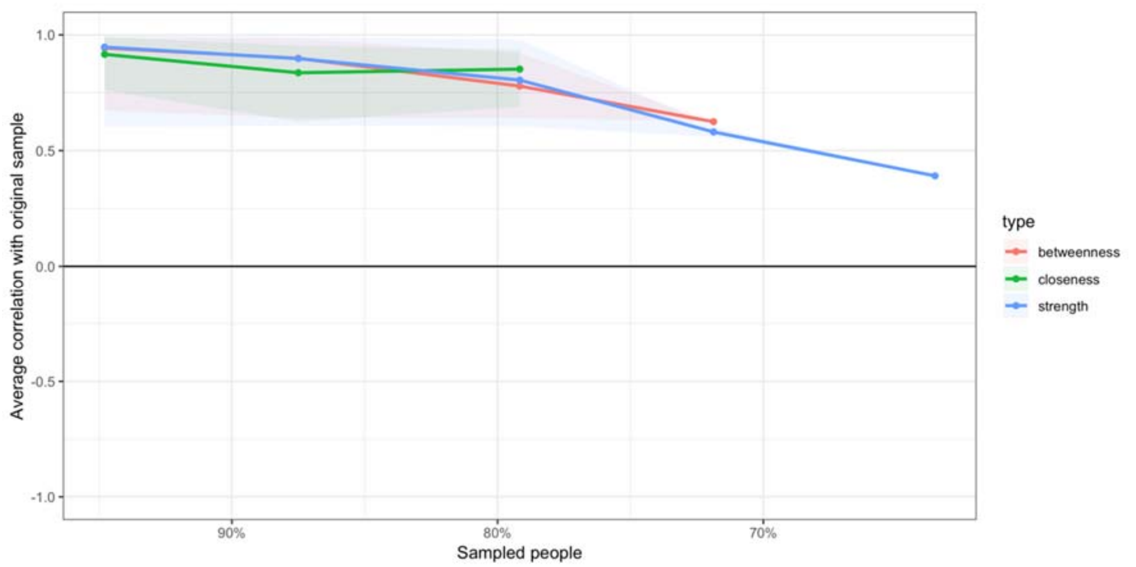


Supplementary Figure 5. 95% bootstrapped CIs around each edge-weight before (panel A) and after CCT (panel B). The red line represents the edge weight for the original sample values, the black line represents the means of the bootstrapped samples and the gray area represents the bootstrapped 95% CIs around each edge. The y-axis labels include all network edges, ordered from the edge with the highest weight (up) to the edge with the lowest weight (down).

Pre-CCT (panel A)



Post-CCT (panel B)



Supplementary Figure 6. Stability of centrality indices before (Panel A) and after CCT (Panel B). The x-axis represents the average correlation and the y-axis represents the percentage of people dropped in the bootstrapped samples. The color lines represent the average correlation between the centrality indices (i.e. strength, betweenness and closeness) of the original sample with the bootstrapped samples, and the areas indicate the range from the 2.5th percentiles to the 97.5th percentiles.

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Roca, P., Diez, G., Castellanos, N., & Vazquez, C. (2019). Does mindfulness change the mind? A novel psychonectome perspective based on Network Analysis. PLoS One, 14(7), e0219793. https://doi.org/10.1371/journal.pone.0219793

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SCIENTIFIC ARTICLES INCLUDED IN THE DISSERTATION

The present doctoral dissertation follows a publication compendium format, including a general introduction, divided into five Chapters, and a general discussion and conclusions. This dissertation comprises the following scientific articles:

- Roca, P., & Vazquez, C. (2020). Brief meditation trainings improve performance in the Emotional Attentional Blink. *Mindfulness, 11*, 1613–1622. https://doi.org/10.1007/s12671 -020-01374-x

- Roca, P., Vazquez, C., Diez, G. G., Brito-Pons, G., & McNally, R. J. Not all types of meditation are the same: Mediators of change in mindfulness and compassion meditation interventions. *Journal of Affective Disorders* (under review).

- Roca, P., Diez, G. G., Castellanos, N., & Vazquez, C. (2019). Does mindfulness change the mind? A novel psychonectome perspective based on Network Analysis. *PloSOne*, 14(7). https://doi.org/10.1371/journal.pone.0219793

- Roca, P., Diez, G. G., McNally, R. J., & Vazquez, C. (2020). The impact of compassion meditation training on psychological variables: A network perspective. *Mindfulness*. doi: 10.1007/s12671-020-01552-x

To integrate each article in the dissertation, each thesis Chapter was accompanied by a brief preamble explaining the importance of the study to both the dissertation and the field of psychology in general.

All coauthors have declared their agreement to the use of these publications as part of the present doctoral dissertation. They have recognized the doctoral candidate as the main author of the publications, giving up the possibility of using these articles as part of any other doctoral dissertations.

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Research Groups

Certainly, a project of this magnitude is never the work of a single person. The research project presented in this doctoral dissertation is the result of the coordinated efforts of different research groups: the research group 'Psychopathology and Positive Mental Health' directed by Professor Carmelo Vázquez (Complutense University of Madrid), 'Nirakara Lab' (UCM Chair of Mindfulness and Cognitive Science) under the direction of Gustavo Diaz and Nazareth Castellanos, and the 'McNally Laboratory for Anxiety and Related Disorders' (Harvard University) directed by Professor Richard J. McNally. In addition, the Mental Health Promotion Network (PROMOSAM - PSI2014-56303-REDT) has promoted the educational formation of the PhD student.

Cover Design

The cover and back cover of this doctoral dissertation were designed by the author (Pablo Roca). This design has no economic or commercial purpose.