PAUL VERHAEGHEN

PRESENCE

How Mindfulness and Meditation Shape Your Brain, Mind, and Life

OXFORD

Presence

Presence

HOW MINDFULNESS AND MEDITATION SHAPE YOUR BRAIN, MIND, AND LIFE

Paul Verhaeghen

OXFORD
UNIVERSITY PRESS

OXFORD
UNIVERSITY PRESS

Oxford University Press is a department of the University of Oxford. It furthers the University's objective of excellence in research, scholarship, and education by publishing worldwide. Oxford is a registered trade mark of Oxford University Press in the UK and certain other countries.

Published in the United States of America by Oxford University Press
198 Madison Avenue, New York, NY 10016, United States of America.

Library of Congress Cataloging-in-Publication Data
Names: Verhaeghen, Paul, author.
Title: Presence : how mindfulness and meditation shape your brain, mind, and life / Paul Verhaeghen.
Description: 1 Edition. | New York : Oxford University Press, [2017] |
Includes bibliographical references and index.
Identifiers: LCCN 2016042416 (print) | LCCN 2016055305 (ebook) |
ISBN 9780199395606 (hardcover : alk. paper) | ISBN 9780199395613 (UPDF) |
ISBN 9780199395620 (EPUB)
Subjects: LCSH: Mindfulness (Psychology) | Meditation. | Mind and body. | Brain.
Classification: LCC BF637.M4 V47 2017 (print) |
LCC BF637.M4 (ebook) | DDC 158/.9—dc23
LC record available at https://lccn.loc.gov/2016042416

1 3 5 7 9 8 6 4 2

Printed by Sheridan Books, Inc., United States of America

This book is dedicated to you.
May you be happy.
May you be safe.
May you be free from harm.
May you be at ease.

{ CONTENTS }

{ PREFACE }

This book began with a bottle of orange juice. A big bottle. Half a gallon of very nice orange juice. Organic, not from concentrate, no pulp.

The intended recipient of said juice was my son, but he no longer wanted it, preferring, I believe, hot chocolate instead.

This was about the fifth time he had changed his mind in the space of a minute or so.

So I did what every parent occasionally dreams of doing: I lifted the bottle—still sealed—high above my head, with both hands, and I smashed it into the kitchen floor with all my might.

The thing exploded.

My son was three years old at the time and so—by all signs and for all intents and purposes—was I.

It took quite some time to clean up the mess—the oak floor, the walls, the ceiling, the stove, the kitchen furniture were all soaked. From time to time we still find two cookbooks joined together by the sticky force of my stupidity.

As one of my favorite writers would say: "So it goes."

As soon as the bottle left my hands, in the suspended moment of my own disbelief that I just *did* that, I of course grasped how very wrong this was, how utterly senseless, how needless, how selfish, how *heedless.*

As episodes of domestic violence go, this one was pretty tame. But still.

Standing there in the aftermath, with my wife and son gaping at dumbfounded me with his beard and glasses dripping with juice, something clicked.

I had just reacted to something that wasn't true. I had had a flicker of a thought in my head, and I had followed it through. I had given a mere flicker of anger a set of black wings, as if I had no say in the matter, as if I had no freedom.

And, of course, in such moments of frustration, you have no freedom.

I realized two things.

One: I did want freedom. I didn't want this—I was better than that, wasn't I?

And two: I vaguely remembered actually being better that that.

So I promised myself to get back to that time. I promised myself to go back to meditation.

I have a checkered past.

I was a Catholic monk for a while, between the ages of 17 and 19—exactly the age when a fruitless yet profound endeavor like that cuts the deepest. The vow of poverty notwithstanding, we lived in a rather magnificent 19th-century house (with a turret, no less) in one of the more quiet, woodsy, opulent outskirts of Brussels.

Part of our training was a 30-day retreat. The retreat was silent, and it involved all the usual accouterments of Catholic monastic life—morning chant, Mass, evening chant—plus four to five hours of meditation. And I loved every second of it. It felt like home. I loved the silence; I loved how it turned time sticky and sweet; I loved my lonely afternoon walks in the nearby forest that was just starting to awaken from its winter slumber. Most of all, I loved what the silence did to my mind—I loved that expansive, lazy concentration, that fluid, softly humming openness, that *presence*.

Then two things happened. One, I fell in love and, two, I started having serious doubts about this whole idea of an interventionist god. Neither of these two developments was very compatible with the monastic lifestyle, and so off I went, on to a degree in psychology.

In the meantime, I somehow forgot to meditate—this whole love thing, I suppose, and then a dissertation to work on, and in general a busy life, very different from the helpful monotony of the cloister.

I have no precise memory of how I stumbled into the contemplative mood again (a long trip to China was partially to blame); this time it took the form of Zen, which I first glossed from books and then, a little later (we're in the mid-1990s now) practiced with a small group at the college where I landed my first job, in Syracuse, New York. Take it from me: Knowing how to sit still for long stretches of time is a great skill to possess in a city that is covered in snow for about eight months of the year.

Zen fitted me well; it felt like home all over again. But then life collapsed around me—my then-wife couldn't bear the snow and her new life in the United States and went back to Belgium, and all other sorts of slow minor social calamities conspired to drop me down into depression. Meditation intensified my distress rather than still it. So I mostly quit the cushion and returned to it only sporadically.

Life is different now.

Since the orange juice incident, I have been meditating every single day (give or take a few). I took care to nurture my practice: I restarted slowly, building up my meditation sessions from 6 minutes a day to my current regimen of 30 to 40 minutes a day during the week and a 90-minute sit on Sundays. I have learned that it is helpful to have friends on this path.

Meditation has simply become a part of my life. It's something I do, like walking the dog, exercising, cooking dinner, or giving our son his evening bath—a habit that roots me, an organic and natural part of the day, nothing special.

It also has, as I was hoping for, changed me for the better. Not spectacularly so: I am far from perfect—never was, chances are I will never be. My budding ability to be more present with whatever is presenting itself makes me just a little more patient, I find, a little more willing to listen, a bit more relaxed, and a little more prepared to insert that all-important half-second pause between thought and action.

This, I find, is a very good recipe for peace and happiness in daily life.

These days, the fashionable term for the meditative experience and its aftermath is *mindfulness*—a sense of being present in the moment, of observing whatever is happening rather than getting caught up in it, and doing so with gentleness and a certain detachment; it is about approaching life with an openness to whatever arises, dropping all preconceptions.

This is aspirational, of course—it is nearly impossible to actually live a mindful life all of the time. It's a near-unattainable ideal. As a consequence, part of the practice of living mindfully is to learn how to fail with grace: Fail, get yourself back to a state resembling mindfulness, fail again, get yourself on track again, and so on. The hope is that ultimately something will come from this perpetual gently guiding yourself back to where you need to be. (As we shall see later in this book, it does—this practice of repeated stumbling does lead to a more lasting habit of mindfulness.)

I discovered that, the more I meditated, the more I found the process itself fascinating—what is it that is actually happening when you sit down on the cushion and turn your attention to your breath entering and leaving your nostrils? I found it equally fascinating to discover what this process gives birth to: I observed an increasing mental clarity, a more positive outlook on life, an increased kindness, and, generally, the gradual awakening of a desire to awaken.

It is one thing to experience this from the inside or to see it happen in friends; it is another to ask the question what good meditation does in a more general sense. As an academic, I was naturally interested in what we can know objectively about this endeavor—what the intrepid researchers who have invited meditators into their psychological laboratories or inside their brain scanners have found. As I learned very quickly when probing PubMed, PsychInfo, and other search engines, there are an unwieldy number of papers on meditation and mindfulness, how they are implemented and imprinted in the brain and/or how they impact your mind and your psychological make-up. Some of that research—likely the studies that make the boldest claims or those with the strongest results—even make it into the popular press.

In my experience, this surfeit of findings leaves many practitioners of mindfulness a little perplexed. I vividly remember a discussion in one of the groups I meditate with, in which someone brought up, with a tangible sense of awe, that she had read that "meditation actually changes your *brain*!" (You could hear both the quotation marks and the exclamation point in her voice.) This didn't exactly seem like news to me (where else would any repeated behavior leave its imprints but in the brain?), but it made me realize that it might be useful for people like her—meditators who are curious to find out what meditation does and how it works but aren't necessarily able or willing, even if they had the requisite background, to devote a few hundred hours to finding and reading the key papers in the field—to have someone (maybe someone like me) plod through all that literature and make sense of it.

Part of the perplexity of some meditators who are confronted with the scientific literature stems from the simple fact that scientific articles aren't aimed at providing the general public with the most transparent information. Instead, they are small parts of a highly specialized ongoing exchange between rarified experts, often couched in near-impenetrable language. Difficulty is added because a large part of the conversation—the broader background, the methodological minutiae, the foundational studies—is left unspoken because it is part of the common history of those rarified experts. Often, the conversation is also cast in adversarial tones—you are explaining to colleague Y and Z why your work is so much better than that of colleague X—which can be quite off-putting to outsiders. A number of excellent review papers and a few excellent meta-analyses (i.e., analyses of analyses; see Chapter 1) can be found, but those are still cast in specialist language, and they don't command the attention in the popular press that a single spectacular study often can.

In sum, it seemed to me that what would help my friend and others like her would be a book aimed at a general audience that would translate all that scientific geek language into an accurate, up-to-date but less overwhelming overview. I should also confess that I very much wanted to read such a book myself.

The age-old advice to writers, of course, is to "'write what you know." If I had taken this advice seriously, I would never have written this book. This isn't my field. Most of my scientific work focuses on attention and memory and how these are affected by the aging process; I have also done some work on creativity and the positive aspects of stubbornly thinking in circles.

Fortunately, I have never taken the "write what you know" mantra as an injunction against stepping outside your comfort zone. Rather, I see this piece of advice as an encouragement to go out in the world, explore, and actively figure out as much as you can about the thing you want or need to know, and then report back. (Maybe that is because this is what you do as an academic: You ask a question and then you set off and discover.)

In some ways, I feel that my status as an outsider might even have some advantages. First, I am not a part of the ongoing conversation, and that allows me, I hope, to listen to all parties without prejudice. Second, in order to be able to follow the conversation, I needed to figure out what the unspoken background knowledge is, what the main threads of the discussion are, and how these threads interconnect. I hope that this effort helped me in translating the work done in the psychologists' and neuroscientists' labs to the pages of this book to, ultimately, your mind.

Of course, I do have my own biases and preconceptions, and I should be clear about those. I am probably positively biased toward this body of research, first because I am a meditator myself, and, second, because, as a card-carrying Buddhist, I have been indoctrinated into the idea that meditation and its consequences are an essential part of a fulfilled life. After writing this book, I am convinced that it would be very hard to argue that meditation is not a good thing for those who find it an enjoyable practice; it is, however, clearly not a cure-all or a magic bullet.

I have another bias as well: Like many scientists, I am, philosophically speaking, a materialist. That is, I see the mind, as most psychologists and neuroscientists do, not as an entity separate from the body but rather as an event, a dynamic experience that springs from the brain. As we often say: The mind is what the brain does. Many meditators, Buddhist meditators included,[1] are, or behave like, substance dualists: There is mind and there is body; they interact, but they are fundamentally different things.

For me personally, scientific materialist explanations do not detract from the mystery or the grandeur of things. For instance, noticing how the stories that I weave about myself drop away as I sink into the relaxation of open monitoring meditation isn't any less wonderful now that I know that this is my posterior cingulate cortex shutting down (we'll get to that in Chapter 3), just like witnessing a moon eclipse isn't any less beautiful or awe-inspiring knowing that it is just our planet's satellite passing through our Earth's shadow. In many ways, I find the scientific worldview inspiring, even in a spiritual context. There is great motivation in the realization that the full extent of my experience originates in those 1,350 or so grams of brain tissue that connect me to the rest of the world—that it is me and no one else who is responsible for my actions and their consequences; that it is me and no one else who will make or break my flourishing as a human being; that it is me and no one else who is the father of my son, the spouse of my wife, the friend of my friends; that it is me and only me that is my interface with the world. For me, the dawning realization that, as a Zen invocation states it, all living beings are one seamless body, moving swiftly from dark to dark, has given some welcome urgency to how I lead my life.

That said, the objectivity of the type of studies that I describe in this book has its drawbacks. The experience of meditating—first-hand—can never be fully recovered in the research about meditating, which by necessity operates from a third-person perspective. Reading about meditation is never going to replace the actual practice.

It is customary to use a book's preface to offer a few guidelines to potential readers. Here are mine.

First, this book is not a book on how to meditate. Plenty of excellent books on the subject exist. Check them out.

Second, this book is not a book on why to meditate. I review the kinds of effects meditation leads to, but those aren't the real reasons, I bet, people meditate. Those reasons, as I have experienced and described already, can change substantially over a meditator's lifetime. And sometimes it turns out that the real reason was something entirely different from what you thought it was.

In his book *Search Inside Yourself,* Google's mindfulness guru Chade-Meng Tan (he goes by Meng) expresses the hope that one day meditation and mindfulness might be as self-evident and nonremarkable as exercise is now. I share Meng's dream, and, as I mentioned, meditation certainly has that place in my life. But it would also be silly to meditate just because research shows that it might improve your well-being and mental health. That motivation seems hardly sustainable to me. (The exercise analogy works well here. I like to run, and I notice an increase in the number of fellow joggers in the streets over the first two weeks of January and then the inevitable decrease to late December levels as motivation runs thin and the reality of muscle ache sets in.) For meditation to really fit with your life, you have to find some pleasure, some fun (or joy, if you're looking for a more spiritual term) in it. If you have given it a fair chance and it doesn't agree with you, maybe you shouldn't torture yourself but find another way to destress that fits you better. I do see this book as a gentle encouragement, in case you need it. The literature is there, showing modest effects from this practice on a wide variety of aspects of the human experience that do matter. That is heartening.

Third, given that this book is on the scientific study of meditation, it isn't going to be an easy read. I will do my best to explain concepts in as plain an English as I can muster, but it might demand a little effort—I will cover a lot of terrain, and in quite some detail. Note that although I see a particular order in the chapters, you should feel free to skip, or to skip around.

This book, in sum, is primarily aimed at the curious meditator, seasoned or beginner. If you've ever wondered what actually happens in your brain as you sit down and focus on the breath flowing in and out of your nostrils, this is the book for you; if you've wondered what kind of psychological aftereffects you might expect from quieting down for half an hour a day, this is the book for you; if you've ever wondered if your meditation experiences fit with other people's experiences, this is the book for you as well.

Finally, prefaces often end with acknowledgments and thank-yous.

The first, largest, and biggest thank-you goes to all those researchers who did the actual studies described here. There are hundreds of them, and many of them toiled in very lonely circumstances way before the concept of mindfulness became fashionable. I am merely a translator of their work, and I bow deeply to their ingenuity and tenacity. Four anonymous reviewers read early drafts very carefully and made many useful suggestions. I bow in deep gratitude to their help, their dedication, and their thoroughness. All remaining mistakes are entirely my own. Big thanks to my editor at Oxford University Press, Joan Bossert, and her assistants, Louis Gulino and Lynnee Argabright, for believing in this project and guiding me along so expertly and elegantly.

In Zen, it is customary to thank your "ancestors"—the countless women and men, "centuries of enlightened women and men" who have spent their time "in the still halls." I would like to name a few of my own recent ancestors. Mark Rotsaert was my first meditation teacher; Terry Keenan my first anchor in Zen; Andrew Quernmore introduced me to *Vipassanā* meditation. I was lucky enough to receive the precepts from Thích Nhất Hạnh in Plum Village in January 2013; I feel very fortunate to have him as my root teacher. I arrived at his monastery through some chance encounters, first with Marilyn Hartman, who kindly showed me the way, and then with Pat Tun, who sternly insisted I go find a community. This book wouldn't have existed without Thay Phap Luu's encouragement to start teaching mindfulness. I thank Al Lingo and the Breathing Heart Sangha for deepening my insights into the true nature of my aspirations. I thank the Insight Meditation Group in Sandy Springs for being such a strong, solid haven, a true group of seekers in the dhamma; in particular, I thank Joel Groover for being such an honest, down-to-earth, and generous non-teacher in wisdom. Thanks go to everyone at Red Clay Sangha for making Zen such a democratic, real, and unrobed experience. A retreat with Stephen Batchelor taught me that the dhamma can be lived in the fullness of the mind as well as the heart. Thanks also to my amazing teachers at the master's program in Buddhist Studies at the University of South-Wales—Nick Swann, Warren Todd, and Sarah Shaw.

A vast amount of thanks go to Monica Halka, who somehow roped me into teaching mindfulness classes to honors students at Georgia Tech—the most fulfilling teaching experience I have ever had. Teaching mindfulness is not sexy (unlike teaching general psychology, with all its flashy demos), not cool (if anything, it seems to have a decidedly nerdy and/or New Age-ish aroma to it), and not particularly fashionable either (to our engineering students, it doesn't quite have the cachet that, say, the concept of sustainability has), but it is truly and utterly *real*. It is probably fair to state that colleges tend to place little value on quietness and well-being, and they don't see an eye toward the collective good as an important value—instead, we typically reward ego and brashness, put a macho spin on the stress of the rat race, and push our students to combative competitiveness. It has been heart-warming to observe the opposite in my classes: to see young minds (and often hearts too) open up over the course of a semester, to feel a sense of community emerge, and to watch a spirit of freedom develop. My first mindfulness seminar in 2013, including my fruitless search for a good textbook, was exactly the impetus I needed to start the actual work on this book. Many thanks too to all my students, who have been incredibly supportive of each other's practice. Big thanks also to Holly Rogers and Libby Webb from the Center for Koru Mindfulness for shaping my mindfulness teaching into something much more competent.

Finally, great big thanks go to Shelley Aikman, my partner in life and meditation, my ultimate sounding board and my ever-present life coach. I bow deeply to her kindness and wisdom, which I can't believe I am fortunate enough to bask in on a daily basis.

Big thanks to you, reader, as well. Your purported existence was a driving force behind writing this book. I wish you all the best in your endeavors, meditative and otherwise.

Presence

{ 1 }

What Is Mindfulness?

In the spring of 1979, on Day 10 of a two-week meditation retreat,[1] the then-34-year-old Jon Kabat-Zinn, a long-term practitioner of yoga and meditation, had "a vision" (his own words), which lasted for about "10 seconds." In that vision, he saw what he later called his "karmic assignment": a model for how to share the essence of meditation and yoga practices (an essence he labeled *mindfulness*) through hospitals and medical centers and clinics across the world—"a practical path to liberation from suffering."

Kabat-Zinn's 10-second vision was the humble beginning of the *mindfulness-based stress reduction* (MBSR) program, implemented first at the Pain Clinic (now the Center for Mindfulness) at the University of Massachusetts Medical School. Since 1979, more than 20,000 people have participated in MBSR programs; the U-Mass database contains more than 480 mindfulness-based health practitioners; a 2007 government survey found that more than 20 million Americans used meditation (often considered to be the tool that leads to mindfulness) for health reasons; and the mindfulness industry was estimated to be worth $4.2 billion in 2009 in the United States alone.[2] Some—notably *Time Magazine* on its January 2014 cover—have called this "the Mindful Revolution."[3]

There are plenty of books on mindfulness too. A casual search on Amazon brings up titles suitable for every area of life[4]: *Mindful Work, The Mindful Way through Depression, The Mindful Way through Stress, The Mindful Way through Anxiety, Mindful Eating* (there are at least eight different books with that title), *The Mindful Diet, The Mindful Athlete, The Mindful Therapist, The Mindful Couple*, which—we hope—experiences *Mindful Loving* (two titles) and *The Joy of Mindful Sex*, which results in *The Mindful Mom-to-Be, Mindful Birthing*, and *Mindful Parenting* (at least four titles), during which they can read their offspring the book *Mindful Monkey, Happy Panda*. Perhaps my favorite among those tomes is the *Color Me Mindful* series—a set of mindful coloring books for adults. It's not hard to find curious commercial aberrations either: One condiment producer sells MindfulMayo® (dairy-free;

"Dollop, mix and smear your way to spread-happy euphoria"); the Budhagirl [*sic*] jewelry line offers mindful glamour ("Turn the routine of getting dressed in the morning into the ritual of presence"), complete with a scientific explanation for why these bracelets work.

Since 2013, mindfulness aficionados even have their own popular magazine—*Mindful*, which comes with a board of advisors that includes academics from the University of Virginia, Duke University, Penn State, the University of Wisconsin, and UCLA; the director of executive development at Google is on this board as well. Since 2010, it even has its own high-impact[5] scientific journal—*Mindfulness*—printed by the venerable Springer publishing house. Typing in the keyword "mindfulness" in my university's library's database of scientific articles produced no less than 50,330 hits. (In case you were wondering—No, I did not read all those papers.)

Big business then, but also serious business.

And, judging from the titles of those books, a concept with wide applicability and a lot of promises.

What is this mindfulness thing? Does it deliver?

What We Are Talking about When We Talk about Mindfulness

Let's start with the first question: What is mindfulness? The definition of mindfulness that seems to resonate most within the movement—just typing in the whole definition into Google resulted in 15,400 hits—is one that Kabat-Zinn coined, almost in passing, in the first pages of his 1994 book *Wherever You Go, There You Are*: Mindfulness is "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally."[6]

Maybe an example will help to show what is meant by this. The author of that 2014 *Time Magazine*'s cover story, Kate Pickert, opens her article with a description of a popular beginner's mindfulness exercise—how to eat a raisin[7] mindfully:

> The raisins sitting in my sweaty palm are getting stickier by the minute. They don't look particularly appealing, but when instructed by my teacher, I take one in my fingers and examine it. I notice that the raisin's skin glistens. Looking closer, I see a small indentation where it once hung from the vine. Eventually, I place the raisin in my mouth and roll the wrinkly little shape over and over with my tongue, feeling its texture. After a while, I push it up against my teeth and slice it open. Then, finally, I chew—very slowly. I'm eating a raisin. But for the first time in my life, I'm doing it differently. I'm doing it mindfully.

Ms. Pickert is eating the raisin, and while she does so, she is paying attention to its visual appearance, its texture, the sensations of its skin bursting open under the pressure of her teeth, the tiny explosion of taste enveloping her mouth, the muscle contractions of swallowing, the aromatic lingerings. She pays attention to this *on purpose*—unlike most of the time when we snack and just pop the food into our mouths, she pays attention to every step of the process, deliberately slowing everything down. She does this *in the present moment*—this is all that fills her awareness—she is not doing anything else, and she lets no memories of raisins past or hankerings for (or maybe fears of) raisins future disrupt her communion with only and precisely this raisin, right here, right now. Finally, she does this *nonjudgmentally*—she is not comparing the raisin with any other raisin, or any other food, and she is not letting herself be swayed by likes or dislikes for the raisin's appearance, texture, or taste; Ms. Pickert just is with the raisin. Put yourself in her place. When you are eating a raisin mindfully, there are just two things in the universe: you and the raisin. Maybe there is just one, actually: *you*—seeing, touching, chewing, tasting, swallowing.

In a very simple way, we can define mindfulness as actually being present in/for whatever it is you are doing, without letting your judging mind (Is this good or bad? Do I like or dislike this?) interfere. If you are listening to Bach, just listen to Bach; if you are dancing to Girl Talk, just dance to Girl Talk; if you are cooking, just cook; if you are sweeping, sweep. *To be fully present*. That is mindfulness.

This does not mean that every moment of your life should be lived nonjudgmentally in the present moment. Stuff needs to get done, so you need to plan; you might want to revisit that fight with your spouse to see how you can do better next time; and—on a grander scale—social or personal change isn't possible without a critical eye filled with wisdom. What mindfulness teachers are saying is that it is good to have mindfulness as a tool in your toolbox, to be used when appropriate or opportune. Part of life's wisdom is figuring out—that is judgment, or discernment, right there—what that appropriate or opportune moment is, and noticing when you have missed it. And then, nonjudgmentally, remind yourself not to miss it next time.

A Mindful Mind Is a Happy Mind

Why be mindful?

One simple and smartly selfish answer is that being present in the moment is associated with happiness, and happiness is one of those things most living beings are quite interested in. You can see this on a small scale: actually *tasting* a good piece of chocolate or a nice mouthful of wine, actually getting an earful of your favorite music, with full concentration, makes you enjoy it (or maybe even life) even more.

Let's widen this up a bit. In a groundbreaking but very simple study, Matt Killingsworth and Dan Gilbert[8] had more than 2,000 people from 83 different countries download an app on their iPhones. The app beeped people at random times during the day, asking them three questions: "How are you feeling right now?" (on a sliding scale from 0 [very bad] to 100[very good]), "What are you doing right now?" (pick one or more from a list of 22 activities), and "Are you thinking about something other than what you're currently doing?" (no; yes, something pleasant; yes, something neutral; yes, something unpleasant).

A first finding was that, generally speaking and as you would expect, some activities made people quite happy (in descending order of happiness: making love, exercising, talking, listening to music, and taking a walk), while others not so much (in descending order of unhappiness: sleep or rest—maybe because the beeps woke you up?—working, being at your home computer, commuting, and grooming). Another finding was that people's minds wandered a lot: On average, people were not with the task 47% of the time. Unexpectedly, the activity people were doing did not have much bearing on whether their mind wandered or not (the one exception was making love—people like to be present for that).

Perhaps unsurprisingly, when people were daydreaming, their mind most often strayed to pleasant topics (42% of the time). You might be tempted to think they were doing this to escape the unhappiness of their present circumstances, but the interesting finding was that people were no happier thinking about pleasant topics than they were when they were simply present with their current activity. And, even more important, how people were feeling was much more related to their level of mindfulness than to the actual activity they were supposed to be engaged in. As the authors state it: "People were less happy when their minds were wandering than when they were not, and this was true during all activities, including the least enjoyable." It really feels better to just *be* there.

In general, then, a mindful mind—or at least a mind that is present for the experience it is having—is a happy mind. (Killingsworth and Gilbert—in what may have been a moment of absent-mindedness—titled their paper with the negative conclusion: *A Wandering Mind Is an Unhappy Mind.*)

This paper raises an important question: If a mindful mind is a happy mind, why aren't we simply mindful all the time?[9] Why do we naturally stray away from this most rudimentary, uncomplicated form of happiness?

The simple answer is that we don't know why we do that. In the next chapter, I discuss the finding that our mind, when asked to be at ease, does nothing of the sort but instead becomes restless and flits from association to association. Buddhist teachers call this "monkey mind"—just like a monkey swings from one branch to the next, lets go, then grabs another branch, lets go again and grasps for another branch, and so on,[10] our minds tend to just go with whatever mental flow is flowing. It's human. It's what we do. In fact, we have a whole network of the brain—the default-mode network—dedicated to just that: to daydream or mind wander (or, as neuroscientists like to call it, "to engage in task-unrelated thought," or—my favorite—"mental time travel"). But *why* that is, what deeper evolutionary origins can explain our mental restlessness, is an open question. I would assume—but I don't know—that part of our restlessness has helped us, as a species, with survival: We're forever pondering our mistakes so we don't need to repeat them, and we're forever wondering what lies behind the next hill, so that we actually get going, out into the world.

Training Mindfulness

A quick look around you will teach you that people differ greatly in their ability to be in the moment. Psychologists have called this ability "trait mindfulness"[11]; in the past decade or so, quite a number of questionnaires have been designed to tap this quality.[12]Typical questions to measure trait mindfulness are: "I watch my feelings without getting lost in them," "When I take a shower or bath, I stay alert to the sensations of water on my body," "I pay attention to how my emotions affect my thoughts and behavior," "In difficult situations, I can pause without immediately reacting," "I am aware of what thoughts are passing through my mind," "When I do things, I get totally wrapped up in them and don't think about anything else," or the opposite of "I rush through activities without being really attentive to them," and "I break or spill things because of being careless, not paying attention, or thinking of something else."[13]

Kabat-Zinn's insight was that although mindfulness may be a *trait*—a knack that certain people possess and others don't—it is also very much a *skill* that can be learned, and thus taught, and that acquiring it would be very useful in people's daily life. For Kabat-Zinn "useful" means what Killingsworth and Gilbert showed—that being mindful can make us happier or, in Kabat-Zinn's more Buddhist terms, that mindfulness can relieve suffering; that is, it can make you feel less stressed, less anxious, less depressed, more open, more content, more joyful.

This is not a new or original idea. Kabat-Zinn's work can be read—in fact he does so himself[14]—as an adaptation of Buddhist principles and techniques to modern Western concerns. Pickert sees this as a first example of smart marketing on Kabat-Zinn's part (we'll get to the second one in the next section): He avoids any talk of spirituality, which would be off-putting to many, but emphasizes that mindful attention is like a muscle—it can be trained. The goal is not to reach some nirvana but to become a little more present, a little less stressed, a little happier—a small, modest, gradual form of awakening: awakening to what you have been missing, to who you are, and to what life is all about.

How do you train your mind to do this?

Kabat-Zinn was not naïve; by the time he had his vision, he was exquisitely proficient in quite a number of contemplative techniques. He had been practicing Zen for 13 years; he was a yoga teacher; he had been director of the Cambridge Zen Center; he was a teacher-in-training under the Korean Zen Master Seung Sahn. He had also been extensively trained within the Theravāda tradition[15]—he was in fact attending a Theravāda retreat at the Insight Meditation Society in Barre, Massachusetts, when inspiration struck. All these traditions rely extensively on meditation as a tool to gain mindfulness, and when Kabat-Zinn started to build his own program, he freely borrowed techniques from each of those traditions.

Except for yoga, all of these traditions trace themselves back to the historical Buddha—teachings that are about 2,500 years old. One of the techniques the Buddha taught extensively[16] was to build a foundation of mindfulness by becoming aware of, first, the body, in particular the breath and the posture; second, of sensations and feelings; third, of the current state of awareness; and, finally, of that what is held in awareness. In the Buddhist tradition, a steady focus on the breath—merely observing, without intervening, while suspending both your judgment and your potential urge to conceptualize, and without reacting to whatever comes up in the mind in the process—has remained one of the prime teaching tools for basic meditation. Meditation is the laboratory, so to speak, in which you learn to develop mindfulness, first by observing it as it occurs (or rather, in the early stages, by observing the seething of its absence), then by deliberatively cultivating it.

Note that because MBSR and other such programs are derived from Buddhism, they have also inherited some of the lingo. To meditate is often called "to sit"; a meditation session itself can be called "a sit." A meditator is sometimes called "a yogi." What you do to foster your mindfulness is often called "the practice"; this term can also be applied more narrowly, so that meditating is also called "practicing." I personally like this concept, because of its inherent double meaning in English—you practice mindfulness both like a musician practices the piano (if you've been meditating for a while, you know that there is definitely artistry involved, and no end in sight) and like a doctor practices medicine (with diligence, aplomb, and selflessness).

Meditation Practices Inspired by Buddhism

Typically, meditation practices that are derived from Buddhist traditions, at least as taught within the context of mindfulness training programs, fall into three categories or styles: focused-attention practices, open-monitoring (also called open-awareness, or choiceless-awareness) practices,[17] and the heart practices. All three of these train or incorporate elements of mindfulness.

In **focused-attention meditation**, the meditator focuses (or tries to focus) his mind on a single object, unwaveringly and clearly. Often, especially for beginners, that object is the *breath*. You concentrate on a region of your body where it is easy for you to pick up the breath (the nostrils, the chest, the abdomen) and simply stay with it. This, it turns out, is hard: The mind starts to wander, sudden itches and twitches and aches pop up and vie for attention, sleepiness creeps in—all sorts of distraction or dullness appear. When that happens, you simply notice them and go calmly back to the breath—over and over again, without judging, without reacting. Sometimes, counting the breath helps—count each outbreath, up to 10, and then back to 1. If you notice you are getting distracted, start again at 1. See how far you get. (Not far. Not to 10.) The goal here is to calm the mind, and to teach it to stay a particular course for a period of time, thus practicing concentration and sustained attention. By doing focused-attention meditation you also learn to observe and monitor the mind, that is, to check for distractions and the absence of distractions. If all goes well, you ultimately learn to be where you are.

Another popular form of focused-attention meditation is the *body scan*.[18] You go on a mental walk through your body, either head to toe or toe to head, and take a few seconds to stay with each body part and note the sensations that are present there—pressure, temperature, vibrations, itches, whatever the particular body part feels like at that moment.[19] The body scan is often an easier practice for beginners because it is a bit more concrete, and the shifting of attention to different regions of the body gives you something more concrete to do.

In all forms of focused-attention meditation, distractions, emotions, memories, or projections will arise. The training consists in meeting those with calm, patience, and kindness and then returning to the object of concentration.

In **open-monitoring meditation**, you open up your awareness to whatever is present in experience, moment to moment, inside the mind. (In Zen, this is called "just sitting.") An open-monitoring meditation typically starts with a few minutes of focused-attention practice to build concentration and calm; then you broaden your focus and wait for whatever arises to arise. The main idea is to make attention become effortless, so that whatever arises—an emotion, the hearing of a sound, a memory, a thought—is simply observed from a distance, like you would observe a cloud in the sky or a leaf on a stream, watching it float by without grasping. In some traditions, experiences are "noted"; that is, a simple label is attached to the moment-to-moment contents of awareness ("itch," "memory," "thinking," "pleasant feeling," "planning," "thinking," and so on). Along the way, you learn to cultivate "reflexive awareness," that is, awareness that refers back on itself. Your mind bears witness to your mind.

The **heart practices** distinguish themselves not by the type of attention that is being cultivated but by the kind of attitude (toward oneself, toward others, toward life) they try to foster—an attitude of positivity, of warm approach, and of interpersonal wisdom. Two flavors have been popular.

The first, in essence a focused-attention practice, is *loving-kindness meditation*, or *metta meditation* (*metta* is the Pali word—Pali is the language of the earliest surviving Buddhist texts—that is translated as loving-kindness; it could also be translated as goodwill, benevolence, or befriending). In this type of meditation, you conjure up a visual image of a series of people, one at a time, and you stay with each of them for a few minutes. The series typically starts with yourself, then a friend, then a neutral person (someone you don't know very well and have no particular feelings toward, maybe the mailman or your bus driver?), then a "difficult" person (someone you have a bit of a hard time with), then an ever-widening circle of people, ultimately encompassing the whole planet.[20] As you stay with the mental image of those people, you repeat phrases of goodwill, directing them toward these people—phrases like "May you be happy; may you be safe; may you be free from harm; may you be at ease." The ultimate goal here is to allow yourself to experience an open benevolence toward everyone you meet, including those people in your life you find difficult to deal with.

A second heart practice, based on the Tibetan tradition of *lojong*[21] (which translates as "mind training") is *compassion training*. This is a more analytical form of meditation—one in which you ponder rather than concentrate. Unlike loving-kindness practice, which is simply the same meditation repeated over and over again until things seep into (and then from) the heart, compassion training typically takes time, unfolding slowly, step by step. For instance, one such program, Cognitively Based Compassion Training,[22] consists of six modules, each taking a week of guided meditations and reflections, moving from focused-attention and open-monitoring basics to reflecting on and cultivating impartiality, gaining appreciation of and affection for others, and generating the skill of empathy, to finally start opening the heart for engaged compassion.

Mindfulness Programs

Kabat-Zinn's MBSR program[23] stretches over eight weeks, with about three hours of class time once a week and a silent one-day retreat during the sixth week. Participants learn four "formal" meditation methods: (a) body scan meditation, (b) sitting meditation (with a mixture of focused-attention and open-monitoring techniques: mindfulness of breath, body, feelings, thoughts, and emotions, and choiceless awareness, as well as some loving-kindness meditation), (c) walking meditation (mindful walking with a focus on the breath, on the sensations in your body as your limbs move, and/or on the outer world), and (d) gentle yoga exercises to be performed mindfully. Informal techniques are added to this, including awareness of pleasant or unpleasant events during the day, awareness of breathing, and mindful awareness of daily activities (eating mindfully, drinking your coffee mindfully, brushing your teeth mindfully, and so on). Homework is 45 minutes of formal and 15 minutes of informal practice per day, six days a week. (As we will see later, the reality is slightly different; in practice, there are fewer contact hours, and participants tend to practice less than recommended.)

The success of the MBSR endeavor has inspired others to build similar programs with different emphases or with additions. A very successful twist is the *mindfulness-based cognitive therapy* program (MBCT), designed by Zindel Segal, Mark Williams, and John Teasdale.[24] This program, which fuses MBSR with cognitive therapy, is intended for the treatment of depression; its explicit goal is to reduce relapse rates. It includes the same formal techniques as MBSR and adds an emphasis on acceptance, allowing, letting be, with explicit classes focusing on how you can recognize and let go of the downward spirals of thought (psychologist call these "rumination") that often start or keep depression alive.

Other therapy-oriented mindfulness programs include *dialectical behavior therapy* (DBT),[25] intended for people living with borderline personality disorders, and *acceptance and commitment therapy* (ACT).[26] These do not include MBSR's formal meditation exercises but work on mindfulness in daily life through the skills of observing, describing, and accepting. ACT explicitly encourages patients to develop an observing self that remains at a non-judgmental distance from the thinking and feeling self—seeing your mere thoughts as mere thoughts and not taking them so personally (i.e., observing yourself thinking that you are a bad person as opposed to concluding that you are a bad person).

Finally, note that there is a recent wave of programs (notably the *ReSource Project*,[27] *Compassion Cultivation Training*,[28] and the aforementioned CBCT) that have gone beyond traditional approaches to mindfulness to include an explicit ethical component. These programs are still mostly grounded in a basic training in mindfulness but have been designed to explicitly promote the skills of empathy and compassion.

There are, of course, countless other classes, courses, workshops, and self-help books that have introduced these or similar techniques to an ever widening audience.

Does Mindfulness Deliver: How Would We Know?

This brings me to the second question I asked at the beginning of this chapter: "Does mindfulness deliver?"

This is the core question that this book tries to answer, and I will need all the remaining chapters in the book to do so.

Before I start this journey, I would like to briefly focus on a preparatory question: How can we find out if mindfulness delivers?

In her *Time Magazine* article, Pickert mentions a second smart marketing move on Kabat-Zinn's part: He started explicitly *studying* the effects of mindfulness on people's lives, more specifically on stress, psychological symptoms, and different aspects of well-being. Pickert formulates this perhaps a bit too much as a deliberate, shrewd move on Kabat-Zinn's part; to me, the therapeutic and research community that has developed around mindfulness really seems to be driven by a sincerely felt, natural curiosity to find out what mindfulness does and does not do.

Since the time of MBSR's inception, the scientific research endeavor has really taken off. There are now literally thousands of papers on how mindfulness affects the brain and mind—in a recent review paper, Madhav Goyal and colleagues[29] retrieved an unbelievable 18,753 of those; an equally improbable 1,468 of those papers contained actual research (though only 47 of those met the most rigorous criteria, as we shall see in Chapter 7). The number of studies is also growing at an incredible clip—in 2006, 121 papers were published on the topic of mindfulness; in 2010, that number was 381; in 2012, there were 672; and in 2014, 1,004.[30]

This is a lot to read. It is certainly too much to comfortably keep up with.

This glut of studies has created its own problems; the biggest problem for anyone new to this field—whether observer or participant—is what to read, that is, where to begin and how to select.

One issue when trying to summarize a literature as vast as this is the possibility of bias. Researchers often come into this field with preconceived notions. Maybe they like the idea of mindfulness; maybe they've been closet meditators half their lives and now they finally see the day that meditation is taken seriously enough for research papers to be published in the highest-ranking journals. This bias may lead to some partiality, even if they're not always aware of it.

The following quote from an interview with Willoughy Britton—one of the smartest and most successful researchers in this field—illustrates this conundrum well:

> My first ten years of practice, when I was also a researcher, I was in that bright-faith phase of "Meditation can fix everything! Everybody should do it!" I wrote a mega-article, the precursor to my dissertation, on all

> of the neurological and biological concomitants to stress and depression. And then I cited all of the studies that suggested meditation could reverse those processes. And I submitted that mega-article to three different journals and it got rejected three times. It finally dawned on me that I was cherry-picking the data. I wasn't actually being a scientist or doing a scientific review; I was writing a persuasive essay.[31]

This cherry picking also happens in the media. I am keeping my eyes open for this, and I often see mindfulness studies discussed on mainstream websites and news aggregators, and the news is invariably positive: Your local newspaper, the magazines you subscribe to, your news aggregator, the blogs you read—they all are much more likely to push a study that shows that meditation "works" than a study that shows it doesn't. This may even just be for the simple reason that a study that doesn't pan out doesn't seem to be so newsworthy—positive results sell. When you read these sources, you will be slowly accumulating the impression that mindfulness is a cure-all and the ultimate route to happiness.[32]

There are two issues here. One is that these positive results are likely to *stack,* or *sum*, in your head. Imagine two studies. Study A finds that meditation helps you concentrate, but it doesn't find any changes in stress. Study B finds that meditation destresses you, but it doesn't find any changes in your ability to concentrate. Your favorite website will probably write up the first study under the headline: "Meditation Helps You Focus" and the second under the headline "Meditation Is a Mental Spa." In your mind, meditation becomes a mental spa that helps you focus—you are stacking or summing the two findings. But the average of Study A and Study B on the ability to concentrate (one positive effect, one null effect) is not that meditation helps you concentrate—it's that it "might" help you concentrate, or that it helps "a bit" with concentration, or, more precisely, that "one out of two studies shows that it helps with concentration." The same goes true for stress: One study finds an effect, the other does not, and the one null finding should temper the enthusiasm generated by the one study that does find the effect. The issue is that the media tend to report only the positive results, not the negative results or the null result, and this risks creating a bias in the mind of the reader.

A second and related point is that reports in the media are more concerned with the presence of an effect ("Study X finds that . . .") than with the *size of the effect*. But in research size does matter. For instance, imagine a study that finds that meditation does have an effect on stress. (It does, by the way—see Chapter 5.) But what does that mean? I would suspect that it almost never means that if you meditate long and hard enough, you will never ever experience stress in your life. (Even the Dalai Lama, by his own admission,[33] feels anger from time to time.)

Let's take a step back.

There are essentially two ways in which the effectiveness of a treatment—mindfulness training, for instance—can be evaluated: as *progress* (i.e., do people feel less stressed out after having gone through MBSR?) and *by comparison* to other treatments or no treatment (e.g., do people who meditate regularly complain less about stress than people who do not meditate?). We can quantify this effect in many ways; the statistic psychologists prefer is called the mean standardized difference. It tells you how many standard deviations (*SD*s) separate the two scores. For instance, an effect size of 1 *SD* for the first type of comparison (progress) would mean that, after training, the average participant has moved down one standard deviation on the stress distribution.[34] An effect size of 1 *SD* for the second measure (comparison with nonmeditators) would mean that the average meditator is one standard deviation less stressed than all nonmeditators.

If you've ever taken statistics, this should mean something to you. If you have not, do not despair. There are other ways to gauge what a particular effect size means.

One method is to give a general ballpark estimate of what a given effect size means. In psychology, the convention is that an effect size of 0.2 *SD* is small, 0.5 is medium, 0.8 is large, and 1.3 is very large.[35]

Another is to benchmark. The effect of aspirin on your risk for myocardial infarction is about 0.04[36] *SD*; the effect of bypass surgery on mortality is 0.15 *SD*; the effect of drug therapy for arthritis is 0.60 *SD*; the effect of psychotherapy is 0.85 *SD*.[37] We can compare the effects of mindfulness to these benchmarks. One very large study of studies on all kinds of psychological, educational, and behavioral treatments found an average effect size of 0.47 *SD* (compared to other treatment or no treatment). This latter number may be a natural benchmark for mindfulness and meditation studies.

A third method, the measure I prefer, is statistical: If the effect size is *X*, we know participants are now doing better than *Y* percent of people. (For the statistics aficionados, you can read these out from a *z* score table; the effect size is the *z* score, and you look up the area under the curve.) If the progress effect size for MBSR is 1 *SD*, this would mean that, after MBSR, the average participant would be less stressed than 84% of people who haven't yet gone through MBSR. In the meditator/nonmeditator comparison, this would mean that the average meditator would be less stressed than 84% of nonmeditators.

The reason to discuss effect size is that when researchers say they "find an effect" or a media outlet mentions that a study found that something "works"—or words to that effect—they do not mean to say that the effect size is large. They mean that a result is "statistically significant." Statistically significant is a technical term; it implies that the researchers have followed the rules of probability theory to make the bet that the results of a study, as they are, are due to chance less than 5% of the time. Statisticians are more willing to take that bet if the effect size is large (for obvious reasons) or when more people are enrolled in the study. If you have, say, 20 people in your study, the results are more likely to be odd than if you have 2,000 participants. (A good analogy might be political polling. I wouldn't trust a presidential poll that used 20 people; 2,000 sounds a lot better.) These odds are calculated using precise formulas. The upshot is that in very large studies, even small effects can become significant; in small studies, the effect needs be whoppingly large (that is not a technical term) to become significant. "Statistically significant"—translated in the media as "mindfulness works"—is thus a term that has a very specific, technical meaning and has little to do with what we normally mean by the term "significant"—something that is meaningful, or large, or useful. For meaningful, large, or useful, we need to look at the actual effect size, which tells us the strength of the effect.

I am forcing all this technical baggage on you for a reason. Looking at effect sizes is very helpful when it comes to combatting the type of bias Britton was talking about. To see if mindfulness has an effect on *X, Y*, or *Z*, you could carefully read all relevant papers (good luck with that!), keep track of all the results, and distill those into a summary. That is what is called a "subjective" or "narrative" review—basically, you present an overview of a field in the form of a story. This story will be filtered, by necessity, through your sensibilities.

The alternative is a "quantitative" or "objective" review, or (the term I use in this book) a "meta-analysis"—an analysis of analyses. In this type of review, you use statistics to pool the results from all studies on a particular topic. Say you want to know what the effect of mindfulness on stress is: You gather all relevant studies, you calculate the effect size for each of those studies, and you average across them all, giving larger weight to the larger studies. If all goes well, anyone who would do the analysis would come to the exact same final number and thus the exact same final conclusion. (That is what makes this type of review objective.) You can also pool brain activation across studies, as we shall see in the next chapter; this allows us to see what brain regions are activated during meditation across multiple studies.

Focusing on effect sizes, then, kills two birds with one stone.[38] First, it allows us to cut through the unconscious bias we might have when exploring the vast amount of studies out there. Second, it gives us an indication of how strong the effects actually are and how they compare to other interventions. In other words, it tells us not just whether mindfulness delivers but also how much it delivers.

In consequence, my own bias in this book will be to gravitate toward existing meta-analyses as objective overviews of specific questions in the field. Here and there, when no meta-analysis yet exists, I conduct my own.[39]

The drawback of this method is that it paints effects with a broad brush: Details of particular studies get lost. Especially in the chapters on the effects of meditation on the brain, I add some of the detail back in—there are lots of studies that have yielded fascinating results using very innovative methods that are simply too interesting to not discuss. In the chapters on the effects of mindfulness on the mind—attention, well-being, stress, and psychological problems—my instincts were to stay a little closer to the meta-analyses and so to use that broader brush.

A final caveat: All the effects reported here (and, in fact, in all research papers) are effects at the group level. They tell us what to expect for the average meditator or the average participant in this or that mindfulness curriculum. Your own mileage may, and will, vary. Even if the effect size for stress would be 1 *SD* (spoiler alert: it is much smaller than that), that doesn't mean that all participants experience the same effect. Some of them might become much more relaxed than that, some of them only a little bit more, and some of them might actually be more stressed out. Some of this is due to chance; sometimes there's a reason for this. Even a very large effect size cannot *guarantee* a positive outcome for any single participant.

This Book

Now that we know what mindfulness is and have some idea of how we can glean its effectiveness from the literature, what can you expect from this book?

When I was an undergraduate, way back in the previous century, my professors talked about meditation as "altered consciousness"—just like your consciousness is altered when you are dreaming or after you've ingested certain drugs, meditation is an experience that is different from your usual walking around in the world. Depending on how you meditate, the outside world may fade away, for instance; your attention may drift in and out of focus; your body sense may change; you may even experience your self and your awareness in a different light. Chapter 2 investigates how meditation, as it happens in real time, impacts the body and brain. What changes occur in your physiology as you sit? What goes on inside your brain as you meditate? Chapter 3 looks more closely at individual studies that investigate how meditation impacts attention, body awareness, and the sense of self as expressed in the brain.

One very old adage in neuroscience is that what fires together wires together. That is, if you activate particular brain regions and the connections between them a lot, chances are that you will craft some lasting changes in these regions and their connections. Chapter 4 looks at the findings. Are meditators' brains wired differently? Do particular regions grow in size? How long does it take for changes in brain structure to take hold? Do they last?

Chapters 5 through 7 examine how these changes play out in daily life, or at least as close to daily life as psychological measures typically get. Chapter 5 focuses on changes in attention; Chapter 6 discusses changes in stress, sleep, personality, and well-being; and Chapter 7 gives an overview of mindfulness as medicine; that is, it examines the effects of mindfulness programs that are used as therapeutic endeavors, mostly for anxiety, depression, and pain.

Chapter 8 is an attempt at bringing this all to a conclusion and to finally answer the question: Does mindfulness deliver?

I hope to provide more than a mere catalog of effects. First, I think it is truly essential to be on the lookout for *convergence* between different levels of results—does activation in specific brain regions as it occurs during meditation leave lasting changes in gray or white matter that in turn lead to transformations in behavior and psychology? In my mind, the story that is so often spun, namely that mindfulness is a valuable life tool, would be all the more convincing if all of its parts were to fit nicely together. Do they?

Second, the question of *how* or *why* mindfulness works is just as vital as the question of whether it works. (Of course, we need to first establish that it works before we can bother with the why.) Within MBSR, Kabat-Zinn talks about the "wise, discerning, embodied, and selfless aspects of awareness itself."[40] This formulation may sound New Age-ish, but it points to two crucial aspects of a developing meditation practice—the training of basic awareness, coupled with the flourishing of trait mindfulness. This description also—implicitly but importantly—points away from another possible explanation, popular in the 1970s, namely that all there is to meditation is a calming, relaxed, parasympathetic antistress response. The question here—to be tackled in Chapters 6 and 7—is to what extent we can explain changes in well-being or psychological symptoms through changes in these two aspects—increased trait mindfulness and more tightly focused and/or lingering sustained and/or more open attention.

Third, I'd like to point to what is still missing in the story. What is it we do not know but should? Where are the explanatory gaps? What are the questions that are open still?

This is quite an agenda. So let's get started!

{ 2 }

Your Body and Brain on Meditation

We begin our tour of the effects of mindfulness and meditation with what actually happens inside you when you sit down to meditate. What is going on, in real time, inside your body (including, of course, the brain)?

To give the main point away at the beginning: Meditation, as seen through this lens, is a story of quiet alertness, a state of calm yet watchful investigation (Jevning and colleagues[1] call it somewhat more poshly “a wakeful hypometabolic integrated response”). In this state, worries, plans, thoughts, time, space, body awareness, and eventually the self—the very experience of who you are—are allowed to slip away, ultimately revealing a frame of mind in which the present can either be truly present or fully transcended.[2]

I examine first (and very briefly) how meditation impacts physiology and turn to its effects on the brain next. To do so, I need to first briefly discuss methods—how does one investigate brain function?—and then introduce you to some brain facts, particularly how the attention networks of the brain are organized. Next, I share results of a meta-analysis on brain and meditation, and this leads me to an exploration of three themes: How meditation changes attention, how it influences body awareness, and how it impacts your sense of self.

Quieting the Body

Most people would agree that meditation is calming. How does that work?

The basic state of the body—whether you feel excited or calm—is regulated by what is called the autonomic nervous system. This system controls the visceral functions of the body—for instance, it regulates how fast your heart beats, the depth and frequency of your breathing, how strongly your pupils react to changes in lighting, how your sexual arousal fluctuates, the progress of your digestion, when you blink your eyes, when you swallow the food you are chewing, or how much to salivate or sweat.

The system is called autonomic because it typically operates in an involuntary way, that is, outside your awareness or your conscious control. (This is a good thing—imagine you'd have to actually remember to blink your eyes, to swallow your saliva when you chew gum, or to consciously initiate each breath.) That doesn't mean that certain aspects of the system cannot be hijacked by conscious control—you can certainly slow down your breathing or hold your breath for a while, or you can take a swallow on command, but most of the time your breathing just happens and you do just the right amount of swallowing for what you're chewing. Other parts of this system are not under your control: Your stomach and guts just churn away, you can't directly control your heart rate, and you can't stop yourself from sweating when you're hot or nervous.

The autonomic nervous system comes in two flavors—the sympathetic system and the parasympathetic system.

The sympathetic system deals with emergencies. It preps you for fight or flight by readying the bodily systems that might need to spring into action. Thus, when something bad happens to you, the sympathetic system increases your heart rate and your breathing rate and it opens up the bronchioles in the lungs so that your muscles and brain can receive more oxygen; it will also release glucose—extra fuel—into the blood stream. At the same time, it shuts down the bodily systems that aren't necessary for the fight-or-flight response—they would just sap much-needed energy away from the action. For instance, in times of excitement, blood flow to the stomach and gut is largely cut off, so digestion stops. You'll also try to dump all the extra weight you can—you might need to make a run for the bathroom.

The parasympathetic system, in contrast, maintains our natural state of relaxation. It calms the body down and keeps its basic functions going. The parasympathetic response has been labeled as "rest and digest" or "feed and breed": Heart rate and breathing rate slow down, digestion proceeds apace, and, if you feel amorous, go for it.

These two systems work in opposition: When one is active, the other is suppressed. You cannot be angry and cool and collected at the same time; it's hard to be at peace with yourself while you're at war with the world.

It will come as no surprise that meditation is primarily an exercise in parasympathetic activation. The first thing you do when you meditate is settle down, often literally in a space of calm—low light, shielded from noise, pleasant smells. You shut out most of the external world and turn to a calming stimulus, often the breath. This settling down can be nicely seen in a set of parasympathetic effects.

First, **heart and breathing rate slow down**. In the four studies I was able to find that provide actual numbers, heart rate went down from, on average, 70.5 beats per minute before meditation—when the meditators were simply sitting relaxed and quietly on the cushion—to, on average, 64.7 beats per minute during actual meditation. Likewise, breathing frequency decreased from 14.3 breath cycles (one in-breath, one out-breath) per minute to 10.7 cycles per minute. Put differently, during quiet rest, one breath cycle takes you, on average, 4.2 seconds; during meditation, one breath takes about 5.6 seconds. There is also a tendency to shift from chest breathing to more diaphragmic breathing (i.e., belly breathing, or deep breathing).[3] The combined effect of these changes is a decrease in oxygen uptake, as well as a decrease in carbon dioxide elimination. This is not a reason to worry—this effect is really small, comparable to what happens during sleep or simple rest.[4] In the one study that reported this, there was a strong negative correlation ($r = -.57$) between the number of years of meditation practice and how much breathing rate slowed down—people who have been meditating longer settle more easily into this state of meditative calm.[5]

Second, **heart rate and breathing rate are synchronized**. For instance, Cysarz and Büssing[6] asked five inexperienced meditators to simply rest, perform mental calculations, or do sitting or walking meditation. There was little coordination between heart rhythm and breathing frequency during rest or math but almost perfect synchronization during either form of meditation (not one on one, of course: There are typically multiple heartbeats per breath). This is likely a natural byproduct of low breathing frequency—slow breathing makes it easier for the heart to get in synch with the breathing pattern. Interestingly, one study found that the heart–breath coupling is strongest at a breathing rate of 10 breaths per minute,[7] which, as we just saw, is the average breathing frequency in meditation. This synchronization is stronger in more experienced meditators[8] and also more regular: For experienced meditators, a ratio of four or five heartbeats per breath was most common (incidentally, this is also the synchronization pattern that occurs during deep sleep); inexperienced meditators do not show a preference for any specific ratio.[9] The end result of heart–breath synchronization is a pervading sense of calm.

There are **other parasympathetic effects** as well, such as an increase in galvanic skin resistance, which is a technical term indicating that during meditation you produce less sweat. There is also an increase in slow brain waves (i.e., alpha waves), also typical of your brain going into relaxation mode.[10]

When this state of calm and relaxation endures for a while—during a retreat, for instance—there can be a decreased need for sleep and food. One study noted a 25% average decrease in sleep duration in participants in a three-month retreat; the kitchen reported a decrease of one-third in food consumption.[11] These changes were particularly conspicuous in those retreatants who reported periods of very strong concentration and mindfulness. One reason may be that long-term meditation, as a relaxed, parasympathetic state, takes over some of the role of non-REM sleep—I'll say a little more about that in Chapter 6. Another reason is that long-term, frequent meditation is likely to lower your metabolic rate, thus reducing your body's nutritional needs.

A side note: These results are clear. At the same time, they also create somewhat of an interpretation problem. Meditation, considered from this angle, looks a lot like any other form of relaxation. In fact, physiologically, meditation can look a lot like sleep. Especially in the mid-1970s, this led to some heated debate, particularly surrounding Transcendental Meditation®. This debate culminated in a few papers that claim that a considerable portion of time spent on the cushion is simply time spent napping.[12] As we shall see, this claim is quite overblown—there is plenty of evidence that attention is actively engaged during meditation.

Breath Suspension

Sometimes meditation can lead to physical experiences that are a bit more unusual. One of these is that during meditation breathing can sometimes simply stop for a few seconds—called breath suspension. Estimates of the duration of these episodes of breath suspension vary: The longest period recorded is 51 seconds[13]; the average over all eight studies I was able to find was 12 seconds. The remarkable thing about these episodes is that after the period of suspension breathing simply resumes as if nothing has happened. Typically when you hold your breath and then allow yourself to breathe again, you will experience postapneic hyperventilation (better known as gasping for air). This does not appear to happen during meditation. During breath suspension, the heart rate slows down further and skin resistance increases. Both of these are signs of high parasympathetic activity, that is, a strong relaxation response during the period when the breath halts.[14]

The estimates regarding how many meditators experience occasional breath suspensions differ widely, from 1 out of 8[15] to 9 out of 10.[16] Breath suspension might also occur more often during Transcendental Meditation® than during any other type of meditation.[17] Research within the Transcendental Meditation® tradition shows that suspensions often coincide with what this tradition calls the experience of "pure consciousness"—"consciousness awake to itself, without thoughts, without sensory input."[18] We do not know what the link between breath suspension and these experiences is, but it is not simply a matter of oxygen deprivation: In one study, control participants (who were also regular practitioners of Transcendental Meditation®) were asked to hold their breath, and they did not report such experiences.[19]

Changes in Body Temperature

Another, much rarer finding[20] is of spontaneous changes in body temperature—feelings of increasing warmth—during meditation. These feelings of warmth (which sadly have so far not been verified by thermometer) are accompanied by a very slow heart rate (on average, 43 beats/minute), as well as a very slow breathing rate (25 seconds or longer per breath). Such very low breathing frequencies in and of themselves are related to the regulation of body temperature,[21] and so the feeling of warmth that sometimes accompanies meditation might be a purely physiological side effect of very slow breathing.

We are entering the realm of the exotic here, but it bears mention that there is one Tibetan meditation practice—*g-tummo*—that is designed to control “inner energy” and has “psychic heat” as its byproduct. This meditation technique has captured the imagination of Westerners for quite a while. In 1929, the Franco-Belgian Tibet explorer Alexandra David-Néel[22] described *g-tummo* practitioners wrapping their naked bodies in wet sheets and generating steam while meditating. Herbert Benson and colleagues studied Indo-Tibetan yogis and reported changes in peripheral body temperature (fingers and toes) of 8.3°C (14°F). They did, however, find no changes in core body temperature.[23]

In a more recent attempt to find out what *g-tummo* is and does, Maria Kozhevnikov and colleagues[24] went directly to the source, a monastery in eastern Tibet. Conducting his study was no mean feat: The monastery where they did the testing was located 4,200 meters (14,000 feet) above sea level, and the room where the monks and nuns were tested was literally freezing.

The monks and nuns explained to the researchers that the *g-tummo* technique has two components. The first is a breathing technique, called “the vase”: The meditator holds her breath and contracts her abdominal and pelvic muscles so that the lower belly sticks out like a vase or pot. This can be done fast and furiously, to generate heat—called “forceful breath”—or it can be done gently and without strain, to maintain heat—“gentle breath.” The second component is an accompanying visualization. During forceful breath, the meditator visualizes a rising flame that starts below her navel and rises up with each breath to the crown of her head; during gentle breath, she imagines her whole body being filled with a surging sensation of bliss and heat.

Kozhevnikov asked her monks and nuns to perform both breathing techniques with or without visualization. It turned out that the only type of meditation that changed core body temperature was forceful breath with visualization—a rise from 36.49° C (97.68° F) to 37.60° C (99.68° F). It also turned out that the nuns and monks who held their breath longer while tensing their muscles had a larger increase in body temperature. Concentration was important too—meditators who were able to generate stronger beta brainwaves (a hallmark of concentration) were faster in reaching their maximum body temperature.

In a second study—and here is the interesting twist—the researchers asked a group of Westerners to try out these techniques. Eleven participants, well-versed in either yoga or martial arts, performed the forceful breath technique but without the visualization. Their core body temperature increased from 36.38° C (97.48° F) to 37.02 ° C (98.64° F). As in the Tibetan monastics, the key was how long the Western yogis could hold their breath. Unlike the Tibetans, and perhaps due to the lack of visualization, the Western yogis were not able to sustain the increase in body temperature for very long.

The conclusion here is that the rise in body temperature generated is modest and caused by how the yogis controlled their bodies—holding their breath, tensing their muscles, or both. The more meditative aspect—the visualization—seems necessary to sustain the concentration needed to keep the body temperature up.

Although this example is exotic and, after we deconstructed it a bit, far removed from what is typically considered to be mindfulness, it is also instructive. A first take-away is that there is nothing mysterious about the mind–body connection in this example—although we don't fully understand the mechanism that regulates body temperature from either muscle tension or holding the breath, all we need to gain this knowledge is a few carefully conducted studies. Likewise, there is nothing strange about visualization or how it works; visualization is simply a very good aid to keep focus and concentration going, which in turn helps to ensure that the breath-holding/muscle-tension technique continues to be applied successfully and with the necessary vigor (or gentleness, depending on the meditation). Again, it would be easy to run a study to find out.

A second take-away from this, it seems to me, is that there might be good reasons behind meditation techniques that have survived the centuries. In the case of *g-tummo*, the two components—the muscle–breath component and the imagination—work together for the dual purpose of heating up the body and sustaining the heat generated. I am not implying here that every traditional meditation technique should be followed to the letter. What I am saying is that finding out what these techniques actually consist of, and studying how and why they work, and perhaps then translating or fine-tuning them for Western audiences, might be a worthwhile enterprise.

How We Look In On the Living Brain in Action

In the first half of the 19th century, a pseudoscience called phrenology was quite popular. Literally, phrenology means "science of the mind"; in reality it was the science (to use that word loosely) of bumps on the skull. Phrenologists considered the mind as a collection of different abilities and faculties, each located in a particular part of the brain's outer layer (the cortex). Better-developed faculties, so it was thought, would take up more brain space; the cranium would helpfully drape itself around this spot and thus create a bump. (In case you were wondering: This is simply not true.) A skilled phrenologist would flutter his hands around your skull and give you an instant readout of your strengths and weaknesses in departments such as Firmness, Destructiveness, Combativeness, Amativeness, or Philoprogenitiveness (i.e., how much you love your children, or, if you don't have any children, how much you would love them if you had them). Ambrose Bierce, in his *The Devil's Dictionary*, famously called phrenology "the science of picking the pocket through the scalp."

It is only recently that we started being able to peek in on what the living brain is doing. This endeavor is called "functional brain imaging"—we take images (pictures or movies) of the brain as it is functioning (i.e., doing whatever it is that brains do). There are essentially two ways in which we can capture such images: By listening in on the electrical activity of neurons or by following the rush of blood to particular areas of the brain. The two most common ways of doing so are scalp electroencephalography (EEG; that is, measuring brainwaves; the first study dates from 1929) and functional magnetic resonance imaging (fMRI), or "scanning", developed in the 1990s.

In EEG studies, participants' scalps are outfitted with a set of electrodes (16, 32, 64, or even more), typically set in a sort of swimming cap with wires coming out of it. The electrodes pick up electrical activity in the brain as it happens, and researchers look at where these signals are located, what the frequency of these signals is, and how they change over time. Note that the brain's electrical activity measured on the outside of the skull is very weak (on the order of millivolts) and that whatever signal we are able to pick up originates from large groups of neurons (thousands of them—all the neurons in the area below the electrode that have approximately a vertical orientation to the scalp). One consequence is that we cannot pinpoint the source of the electrical activity exactly. Another consequence is that it typically requires many repetitions—many research participants repeating the task often—before a coherent picture emerges. There is simply a lot of noise and not a very strong signal.

In fMRI studies, participants are slid into the cylindrical tube of an magnetic resonance imaging (MRI) scanner. Here is how his works: When neurons have recently fired,[25] they need to replete their energy source, and so blood rushes in to deliver oxygen; this rush of fresh, oxygen-rich blood is what the scanner picks up. It does so by using a combination of a powerful magnetic field (about 50,000 times stronger than the earth's magnetic field) and radio waves; the resulting measure is called the blood-oxygenation-level dependent (BOLD) response. With the fMRI method, we can pinpoint pretty accurately what brain regions were recently active—the precision is about 1 mm for most research MRI scanners. However, because blood flow is relatively sluggish (the BOLD response peaks about five to six seconds after the event that provoked it), we cannot measure the timing of that activation as accurately as we can with EEG.

Looking In On the Meditating Brain

How can we use these methods to find out how the brain does meditation?

EEG research on meditation has focused mainly on the frequency of the brainwaves that can be detected (five frequency bands can be distinguished: delta, theta, alpha, beta, and gamma, from slowest to fastest) and the general location of each type of wave. To grossly oversimplify, the main result from this work is that meditation tends to increase the amplitude[26] of slow waves—theta and alpha mostly—but not much is clear beyond that.[27]

Such slow waves are often seen when people get drowsy, and so—as I mentioned earlier—some scholars have used these reports to claim that meditating brains simply go into idling mode. Some, especially in the 1970s, have even gone so far as to state that this work shows that meditators are simply asleep. Currently, the same neuroscientists, or at least their successors, have realized that they are not so sure. The reason for this is that we are becoming increasingly aware that brainwave frequencies are still poorly understood. Only recently, for instance, have we become aware that alpha activity—often a sign of drowsiness—can also mean that the brain is actively clamping down activation in particular brain regions, quieting them down. This makes for a very different interpretation of the meditative state—instead of dozing off, meditators might be actively engaged in curbing the many meanderings of the wandering mind. There is, however, little in the brainwaves themselves that can help us to tell these two possibilities—drowsy or alert—apart. With the advent of fMRI research in the 1990s, this particular ambiguity got resolved, as we will see later. (Spoiler alert: The latter of the two hypotheses is correct. Meditators are very much awake and active participators in the process.)

In **fMRI research**, the standard method to find out what brain regions are responsible for a particular task is called the subtraction method. The brain is continuously on the go (so much that it hogs about 25% of the body's energy supply, even though it accounts for only about 2% of the body's weight), and so simply noting what parts are active during a particular task will tell us little of use—there is always something going on somewhere in the brain. The subtraction method serves to isolate brain regions that are actually doing the task we are interested in.

Here is a simple example to illustrate this. Assume that I am interested in how good you are at controlling your attention, that is, to direct it to where you want it to go and exclude everything else. A standard test for this is the so-called Stroop task, named after the person who invented it. In this test, you are presented with a set of color words (like the word "green") printed in a color that is different from what the word says (like the word "green" printed in red ink). Your task is to say out loud what the ink color is, ignoring the meaning of the word. If we would be simply looking at what parts of your brain are activated as you do this task, we would learn very little. That is, attention would be part of the mix, but we would also see activation in brain regions that have nothing to do with how well you are able to control your attention—regions that deal with vision, for instance, or with understanding and naming colors, or with remembering what it is again you were supposed to be doing. What we need to do in order to see what attention does to your brain is to get rid of all these other processes. The easiest way to do this is to build a task that does everything the Stroop task does, minus the attention part—a *control* or *baseline* condition. For instance, I could have you tell me the color of colored words that do not denote a color (words like "chair" or "bed"). We take the activation patterns in the Stroop test and subtract brain activation patterns in the control condition from it, and—voila!—we now know what brain regions are activated in the attention-control part of the Stroop.

You can see the problem for meditation research here: What would be a good baseline or control condition? What do we compare meditation to?

Researchers in the field typically use one of two methods to compare meditation to a meaningful baseline. One method is to compare brain activation in seasoned meditators during meditation with activation in these same meditators during a so-called resting or at-rest condition in which they simply lie in the scanner and do nothing. A second method is to compare what happens to seasoned meditators during meditation with what happens to novice meditators or nonmeditators during meditation.

These methods come with their own issues. We don't know very well what people are actually doing when they are asked to lie in the scanner and rest and do nothing (as we will see later, for seasoned meditators the answer may very well be that they start meditating anyway). We also have no good grasp on what the minds of newly instructed novices are doing when they are attempting to meditate.

More recent studies try to circumvent these problems by using an approach called *neurophenomenology*.[28] In this approach, participants tell the researchers about their experiences in the scanner (that is the phenomenology part), and researchers then relate these reports to brain activation (that is the neuro part). For instance, in one study we will look at in more detail in Chapter 3, meditators were asked to meditate from a selfless vantage point—to experience what was happening but without placing themselves at the center. After they came out of the scanner, the meditators described their experiences to the researchers; these reports were sorted into different categories or levels of selflessness. Finally, the researchers looked for different brain patterns depending on these categories to find out what parts of the brain were associated with these experiences. This approach gives validation and weight to people's first-hand experiences and also allows the neuroscientists to check on their conclusions concerning what it is the brain does when its owner sits down to meditate.

One drawback of the neurophenomenological method is that it requires trust in the participants' reports. The problem isn't so much that participants might be lying but that they might not be very precise in their descriptions or—perhaps more likely—that what they experience might be hard to put into words.

The era of neurophenomenology has also led to an interest in *manipulating* meditative states—for instance, by asking participants to meditate a certain way (as in the selfless meditation example) or (in another study we will look at in more depth in Chapter 3) by giving them feedback about what is happening on the neural front and asking them to tune in to that feedback. The changes in experience can then be related to changes in brain activation.

There is one other practical issue worth mentioning here. Most meditation techniques require the meditator to sit upright on a cushion, a kneeling bench, or a chair. One of the reasons for this is to promote alertness and focus. To further help with concentration, the meditation environment is typically set up so that nothing much disturbs the senses—you typically sit in a quiet, comfortable, low-lit space, with perhaps some incense, a candle, or particular images, all of which become cues that over time become associated with the meditative state. Some ritual may be involved as well—you might light the incense using a particular set of gestures, or you might bow, or sound a bell, or start your sit with a particular phrase or chant. Sometimes the time and space and ritual are shared with friends.

The brain scanner environment is almost the exact opposite of that quiet, comfortable space: After emptying your pockets of anything magnetic, you enter a clean, sanitized hospital-style room with harsh lighting. In the center of that room you find a medium-sized spaceship. You are invited to lie down on a stretcher that slides down a narrow tube into the innards of said spaceship. You are given foam earplugs and headphones to wear. The reason for the earplugs becomes evident as soon as the machine starts scanning. Paul Broks calls an MRI scan "the magnetic gaze."[29] That is a bit of a misnomer: A gaze is not just scrutinizing and concentrated; it is also steadfast and silent. An MRI scanner is anything but—with some of the procedures, you have the distinct feeling that your whole body is being rattled—and a scan is *loud* (about 120 decibels for a current state-of-the-art system). The noise level is equivalent to a live rock concert, a jack hammer three feet away, or a jet engine 300 feet away[30]—not an environment conducive to relaxation or concentration. One side effect of this is that researchers in this field, as we shall see shortly, prefer to use very experienced meditators as their research participants—they are less easily shaken by their external environment.

From Glob to Grid: Weaving the Networks of the Mind

Earlier in this chapter, I mentioned phrenology—the pseudoscience of examining bumps on the head. Current-day fMRI research leads to pretty pictures, and with it, some researchers note, the danger of a new "technicolor phrenology," sometimes dubbed "blobology."[31] That is, we might be able to pinpoint different areas of the brain that are active while you meditate, but, even if this is true, does this tell us anything interesting?

Let me backtrack a little here and illustrate what I mean by "the dangers of blobology" by borrowing an example from a very different field in neuroscience—face recognition. There is a specific area in the brain, in a structure called the fusiform gyrus, that is particularly active when faces are shown but that does not react to objects, places, or scrambled faces; this region is hence known as the fusiform face area (FFA).[32] (An analogy in meditation would be to find "the meditation area" or maybe "the open-monitoring area," the "focused-attention area," or "the loving-kindness area," which, of course, do not exist.) In the past decade or so, it has become clear that there are some problems with this interpretation of the FFA. One is that the simple equation *FFA = recognizing faces* doesn't work. The FFA turned out to not only be interested in faces; it also lights up for any complex visual thing you have a particular expertise in. If you are a connoisseur of vintage cars, your FFA acts as your fusiform vintage car area; if you read Chinese, the FFA is your fusiform Chinese-character area. One lesson here is that even if we would find "the" meditation area, it would likely be doing other things as well, and what those other things are would be informative. (In case of the FFA, subsequent studies have taught that there is nothing special or innate about processing human faces—it's just something we have all acquired exquisite expertise in.)

There has been an even more important course correction to blobology, and that is the growing understanding that brain regions do not operate in isolation. The brain is a tightly connected web, and the resulting teamwork of regions is crucial to understanding what is really happening. To return to the FFA example: There is a rare disorder called Capgras syndrome, or imposter syndrome, where the patient (typically after a stroke or accident) can still recognize faces but now has the bewildering feeling that all the people around him have been replaced with perfect replicas—imposters. ("This person looks like my mom, but she *isn't* my mom—there's something off about her.") The cause of this curious syndrome is that the connection between the FFA and the foremost emotional part of the brain (the amygdala) has been cut. The consequence is that Capgras patients can still recognize people, and also still experience emotions, but the connection between faces and emotions is gone. This leads to the eerie feeling that Mom is no longer Mom—you no longer feel the emotional oomph you should get when you see your mom, and so you sense that something is not quite right.

What this example shows is that the brain is not a connection of loose parts. Rather, the brain works like a team where each member plays its role—or actually more like a set of teams, akin to a construction crew or a kitchen line. We can find out what brain regions belong on the same team (the term typically used in neuroscience for team is "network") by looking at anatomical connections (white matter fibers between regions; this is called "anatomical connectivity") and also by examining what brain areas tend to be activated or deactivated together (called "functional connectivity").

The brain has many different networks—more than 20 major ones have been identified.[33] These networks do such diverse things as identifying shapes, understanding speech, holding on to fleeting information, creating lasting memories, preparing the body for action, or experiencing emotions.

Three of these 20-odd networks seem particularly relevant for meditation: The so-called default-mode network and the two attention networks—the "salience network" and the "executive-control network." Figure 1 shows you the anatomy of the core hubs of these networks.

What are these networks and what do they do?

The **default-mode network** was discovered and named by Marcus Raichle.[34] It was a chance discovery.

Earlier I mentioned that brain scan studies use a control or baseline condition; often this baseline condition is just a resting condition—you are asked to lie still and simply relax. Raichle's discovery was that during this period of rest the brains' activity levels didn't go down to zero: The brains of his research participants were no less active during this resting period than when they were asked to pay attention and engage in a particular task. Even more interesting, during this resting period, the patterns of activation and

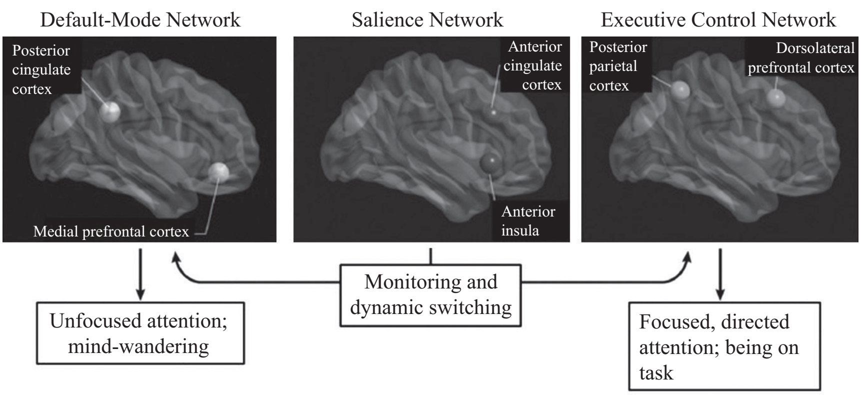

FIGURE 1 *The core hubs of the default-mode network and the two attention networks (adapted from Uddin, 2015).*

deactivation in specific areas of the brain (the medial prefrontal cortex, the posterior cingulate cortex, the precuneus or lateral parietal cortex, and a few others) fluctuated together—when one went up, the others did too; when one went down, so did the others. In other words, these areas formed a network. Intriguingly, activation in this network quieted down when the participants started doing the actual study they came in for. In other words, this is a network that is active when you're not doing anything in particular, but it switches off when you need to focus on doing something in the outside world.

Raichle's original idea was that this network captures the brain's default mode—its idling mode, so to speak. For a while, he tried to label this the brain's "dark energy," but it was the more boring term "default-mode network" that stuck.

Later work has shown that the default mode isn't really a default; the brain isn't really idling. (It never is.) This is something that in retrospect seems blatantly obvious: When you are resting in the scanner, your body may be immobile, but your mind is hardly languishing. It is much more likely that your mind will be superbly active—meandering and freewheeling, jumping from fleeting thought to fleeting thought, watching memories surface and making plans for the glorious moment when you will get out of the scanner tube. We know this because the default-mode network also clicks on when people are asked to produce associations (e.g., "Find a verb that goes with the word 'hammer' "),[35] or to retrieve memories, or to imagine themselves in some future scenario, or to take someone else's perspective in a dialogue.[36] Randy Buckner called these mental musings "self-relevant mental simulations," but they are probably better known to all of us as daydreaming, mind-wandering or—in the context of meditation—monkey mind.

Recent work has further subdivided the default-mode network into three parts: A core hub (consisting of the posterior cingulate cortex and the anterior medial prefrontal cortex) and two subsystems that interact with that hub.[37] The first subsystem (consisting of the dorsal medial prefrontal cortex, lateral temporal cortex, temporal parietal junction, and temporal pole) serves to represent your current situation or mental state; the second subsystem (consisting of the hippocampal formation, parahippocampal complex, retrosplenial cortex, parietal lobe, and ventromedial prefrontal cortex) is active when imagining the future and reliving the past—mental time travel. (If all these anatomical terms make you a bit dizzy—don't worry. If and when these—and other—brain regions return later in this book, I will remind you of their function.)

The **attention networks** typically seesaw with the default-mode network: When the default network is engaged, one or the other attention networks usually are not and vice versa.

Neuroscientists have uncovered a number of attention networks; two that are often emphasized are the salience network and the executive network.[38]

The **salience network,** sometimes also called the dorsal attention network, has the anterior cingulate cortex and the anterior insula as its main regions. “Salience” is psychology-speak for something that stands out—something that is (to get a little circular in the reasoning here) attention grabbing. The salience network is involved in detecting changes and events that are relevant for what you are doing or want to do, so that you can reorient your attention and act accordingly.[39] In the context of meditation, the salience network would be detecting whether you have started daydreaming or whether you have strayed from the breath.[40] The salience network has direct connections with brain regions that are part of the emotion and motivation system—the amygdala (a structure specializing in gut-reaction emotions), the substantia nigra, and the thalamus.

A second important attention network is the **executive network**, sometimes also called the frontoparietal network. It consists of the dorsolateral prefrontal cortex and the posterior parietal cortex. The executive network directs where your attention is going and also helps with setting the right amount of effort for a particular task. In the context of meditation, the executive network could be involved in fine-tuning of effort, in directing or redirecting the wandering mind (detected by the salience network) to the breath, or in letting go of an emotion that arises.

Meta-Analzying the Meditating Brain: Tomasino’s Map

Where to start our investigation into the meditating brain?

The first thing to note is that there are quite a number of studies out there and a growing number of review articles as well.[41] These give very detailed overviews of the neuroimaging work in this field. Most of those reviews are written for specialists, that is, neuroscientists working on this topic—they might need some translation in plainer English before they are digestible by most of us.

A second thing to note is that most of these reviews are of the so-called narrative variety. As I mentioned in Chapter 1, such reviews tell a story—the story that emerges in the reviewer’s mind after she reads the literature. That story is subjective: Someone else reading the same articles might come away with a different conclusion. There is no escaping this: Not all studies point to the same conclusions, and that makes it necessary for reviewers to make choices. In much of this book, I will be guilty of this too: I will guide you through a large number of studies, and I will draw some conclusions, but those do not emerge automatically—I will arrange the studies in a certain way and emphasize certain outcomes more than others. There is simply no other way to bring together a very varied, mixed set of studies that are all, in their own way, trying to answer a large number of quite subtle questions.

As I also mentioned in Chapter 1, meta-analysis is a more objective way to answer the single, more simple question we are interested in here: What brain regions are active when people meditate? A meta-analysis on brain activations simply pools the results from all relevant studies. It looks at convergence between studies, and not all studies activate the same brain regions. If, say, you analyze three meditation studies and Study 1 finds activation in brain region A, B, and C; Study 2 finds them in region B, D, and E; and Study 3 finds them in A, B, and D, the conclusion will be that meditation activates region B a lot, A and D a little less, and C and E to an even smaller extent. (The actual statistics are more complicated, but this is the gist.) The end product is a map of regions and how much each of these is activated on average. Thus only outcomes that appear in multiple studies are likely to be represented; it also implies that regions that have only been found in a few studies are not likely to show up as significant. Additionally, studies with a larger number of participants are given greater weight in the analysis.

Again, this way of looking at the evidence stands somewhat in contrast to how most of us (I think) read the scientific literature, especially as it comes through to us in blogs and newspapers or magazines or other media: Study 1 finds activation in Region A, Study 2 in Region B, and Study 3 in Region C, and a natural inclination might then be to conclude that meditation activates all three of these regions. In a meta-analysis, none of those regions might turn up significant because, for each region, the single positive effect that was found is being diluted by the two zero effects (the lack of effect in Region A in Studies 2 and 3, Region B in Studies 1 and 3, and Region C in Studies A and B). Another way of stating the same point is that meta-analysis rewards one of the most hallowed principles of science: If a result does not replicate, it should not count for much.

There are to date two meta-analyses of brain activations during meditation; the later one, by Antonietta Tomasino and colleagues[42] contains all the data from the earlier one,[43] so I will focus here on Tomasino et al.'s.[44] Their map is reproduced in Figure 2: This, then, is your brain on meditation!

If at first glance Tomasino's map leaves you a tad underwhelmed—what is going on with all these little pinpricks; where is the big pattern?—you can be forgiven. Meta-analysis works very well when the brain's response to a particular task is consistent—when a single region or a few regions shows or show strong activation or strong deactivation. Such precision is likely when all studies reflect the exact same process. A good example is the Stroop effect I mentioned earlier—people are slow in naming the color of color words that are printed in a different color than the color they refer to, like the word "red" printed in green. In a meta-analysis of this task, there is very precise localization of the effect.[45] It makes sense that meditation is not like this at all—there are likely lots of different processes going on. To complicate matters, these

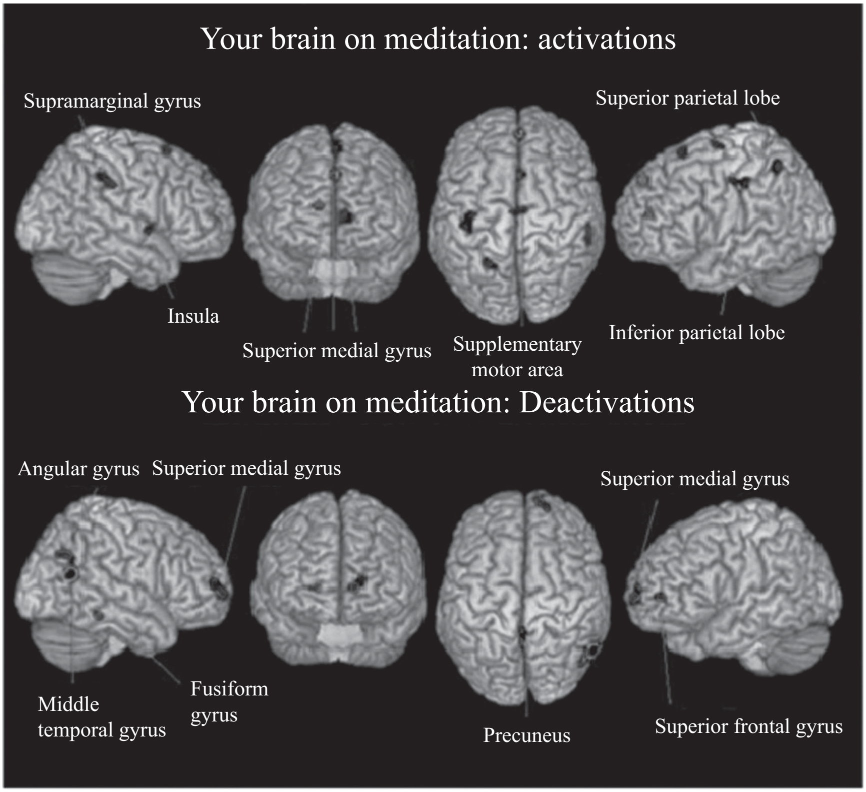

FIGURE 2 *Tomasino et al.'s map: Areas of the brain that are activated (top) and deactivated (bottom) during meditation (adapted from Tomasino et al., 2013).*

may be different in different types of meditation, they may vary by the level of experience of the meditators, and so on.

Another thing to keep in mind is that meditation studies likely also capture brain activation in regions that have little to do with our idealized picture of what meditation is. Meditation is, in practice, a deeply flawed endeavor. We all know that the ideal of focused-attention meditation is to keep the mind focused, but many of us (if not most of us, or virtually all of us) can testify that that is not what is actually happening—the mind very easily goes off-leash.[46] What the fMRI analysis picks up is both the intended process of meditation and its failure, and there is little we can do to distinguish one from the other. (In Chapter 3 I discuss studies from two research teams—Brewer's and Hasenkamp's—that have cleverly managed to do so.)

Note that my emphasis on Tomasino's map does not mean that this is the final arbiter of brain activations during meditation. Derived from a meta-analysis, this map is only a rough approximation of the actual terrain. I use it here as a guide, setting us up for the journey of the next chapter, where we will explore some of that actual terrain, that is, the details of some of the actual studies.

Studies that Comprise Tomasino's Map

Before I take you on a tour of Tomasino's map, I should guide you through some of the characteristics of the studies that went into it.

Tomasino's map collects the results from 26 studies, reporting on a total of 313 participants. Because some participants were tested in more than one study or condition, the number of actual people tested is smaller still, namely 219—about the size of a typical freshman Psych 101 class at a large state college or the number of people that fit into an average movie theater. This is also a group with a tremendous amount of meditation experience (11,552 lifetime hours on average, to be precise[47]). A full 21% of them are Buddhist monastics (all male, and most of them Asian, that is, Tibetan or Japanese). It also seems that most if not all of these individuals practice meditation in a religious context, mostly Buddhist, but some hail from the Vedic/Hindu tradition. To put the average amount of expertise in perspective: If you would meditate an hour each day (which for most of us is already quite a lot), you would hit 11,552 hours after 31 years and 8 months of practice; if you would sneak in an intensive seven-week retreat or two each year, you would get there after 23 and a half years. Some of the individuals in this group probably arrived there much faster: Tibetan monks often meditate multiple hours per day, and their lifetime practice would also include multiple, long retreats, each lasting months or years. What is clear, then, is that Tomasino's map is drawn on the basis of a small and highly exceptional group, hardly representative of your typical Western meditator or mindfulness practitioner. These people can perhaps best be described as meditation professionals—they are meditators in the same way that I am a college professor (except that they get paid a lot less, I fear, and they don't get summers off). Actually, my guess is that there are far fewer of them than there are college professors, so maybe they are described even more aptly as the professional athletes of meditation (even more underpaid but still always practicing).

At first blush, this is a bit odd. If you wanted to know what exercise can do for you and you keep yourself at, say, the Centers for Disease Control and Prevention–recommended 20 minutes per day of moderate exercise, it wouldn't be particularly helpful to study the physiology of Michael Phelps, Usain Bolt, or Serena Williams (or whoever your favorite athlete is). If you wanted to know what your own brain on meditation looked like, and maybe get some practical pointers from what other people's brain on meditation looks like, you might not immediately want to turn to the brain of a Tibetan monk who has spent the last 10 years of his life doing little else than meditate.

Yet this bias is also understandable from the researcher's point of view. It is, in fact, probably the only practical way to get at a brain-on-meditation map.

First, as I described earlier, meditation circumstances in the fMRI lab are less than ideal. If we want to know what meditation looks like in the scanner, we need to do this research with people who are actually able to meditate on command lying flat on their back inside a very noisy, claustrophobic tube.

Second, we need to make sure not only that the meditators we study are doing what we ask them to do (e.g., keep mind wandering to a minimum) but also that they can follow the instructions and directions necessary for the study. Often the designs used in the scanner require that meditators turn the meditation state on and off within seconds or that they switch between different types of meditations rather swiftly. That's a job for true meditation experts.

There is a further, more hidden advantage of using experts for these studies: Such studies can offer mere mortals like us, who are advancing somewhere along the mountain but are nowhere near its peak, a tantalizing glimpse of what the view from the top might look like. As just one example, our teachers often tell us that it is possible to experience your sense of self dropping away—that is, there is still something to experience, but the "you" who experiences it is no longer there, separate from the experience. Work with very advanced practitioners, discussed later, shows that this is indeed the case. I find such findings inspiring. (Although I admit they also make the climb—see how far I still am from the top?—look a bit daunting.)

Your Brain on Meditation: A Tour of Tomasino's Map

What can we then learn from the modest field of fireflies in Figure 2?

I would argue that the map shows that four networks are implicated in meditation, namely the two networks that deal with attention, the network that creates the sense of self, and brain regions that are concerned with perceptions of the body.[48] Let's look at each of those in turn.

First, meditating implies **controlling attention**, or at least a valiant attempt to do so. On Tomasino's brain map, we can see this in activation of the superior and inferior parietal lobe, both part of the *executive control network*. The inferior parietal lobe is directly connected to the default network.[49] Activation in these brain regions might then mean that meditators are—as expected—focusing their attention on the object of their meditation. Activation in the inferior parietal lobe may additionally indicate that they are at the same time suppressing the activation of the default-mode network, actively guarding the mind against mind-wandering or daydreaming. This attempt appears to meet with some success: The map of deactivations shows a quieting of some parts of the *default-mode network*, notably the angular gyrus, the middle temporal gyrus, and the precuneus.

Second, meditating implies a **particular experience of the self**. In Tomasino's map, we see stronger activation of the medial prefrontal cortex (more specifically, the superior medial gyrus) and deactivation of the precuneus. Both of these regions are involved in the so-called self-referential processing but at different levels. (I return to these levels in a bit more detail in the next chapter when I discuss self-experiences and meditation more explicitly.) "Self-referential processing" is psychology-speak to indicate that these areas perk up when there is a question that involves the "I." For instance, both areas (along with a bunch of others) become active when people are asked to reflect on questions such as "Am I a good friend?" but not when they are asked to reflect on general questions such as "Do you need water to live?"[50]

The *precuneus*—deactivated on the Tomasino map—is part of the default-mode network. It is involved in the so-called narrative self, that is, the part of you that spins stories about yourself, the part, if you wish, that constructs your persona. This region typically lights up when you retrieve personal memories, when you make judgments about your personality (e.g., "Does the word 'talented' describe how I typically feel and think about myself?"), or when you compare yourself to others ("Am I more honest than the president of the United States?").[51]

The *ventral medial prefrontal cortex*, in contrast, becomes activated rather than deactivated during meditation. This region is also part of the default-mode and self-referential networks, but it is not as reflective as the precuneus. The self that the ventral medial prefrontal cortex builds is more the observing "I" that is experiencing the world and recognizes these experiences as belonging to itself.[52] For instance, the ventral medial prefrontal cortex can tell the difference between an object that is yours ("my pen") and one that belongs to somebody else ("a pen").[53] More important perhaps, the ventral medial prefrontal cortex specializes in self-relevant emotion: It turns on when you are asked to check whether emotional words apply to yourself[54] or when you are asked to judge whether you can personally relate to a set of emotional pictures.[55]

The brief conclusion here is that meditating appears to suspend some of the involved storytelling you weave about yourself in daily life. Instead, as many meditation teachers tell us,[56] you become more of an observer, turn inward, get in tune with and take possession of your emotions.

A third aspect of meditation gleaned from Tomasino's map is a **change in body awareness**. This is a two-fold story, with seemingly contradictory conclusions: One is a story of increased awareness and sensitivity and the other of decreased awareness and sensitivity. You may have had this experience in meditation yourself: When you pay attention to the breath, you naturally become very keenly aware of the breath, to the point where you can feel yourself almost *becoming* the breath. When this happens, the rest of "you," and maybe particularly your sense of where you are and where your body starts and ends, quietly slips outside awareness. So, in the meditation experience, a *strong, explicit focus on one aspect of the body* can be accompanied by a *an increasing sense of disembodiment*.

This split is reflected beautifully in Tomasino's map.

At the level of detailed and explicit focus, the map shows activation in regions that are associated with direct body awareness, namely the superior parietal lobe, the postcentral gyrus, and the right insula. One meditation study has shown that these areas are activated when experienced meditators meditate on bodily sensations, more specifically on the weight of different body parts.[57] This corner of Tomasino's map may thus represent the effects of concentration techniques that specifically involve the body—paying attention to the varied sensations of the breath or investigating minute shifts in tension, temperature, and vibrations in the skin and muscle during a body scan meditation. All of this makes these sensations more palpable, and you can see this in activation in these particular brain areas.

On the more global level of body awareness, Tomasino's map shows decreased activity in the right angular gyrus and increased activity in the supramarginal gyrus. The right angular gyrus is responsible for integrating information from the different senses to create a consistent image of where you are situated in space. Creating this image is a fine balancing act. Disturbing that balance by providing this region either with too much stimulation (i.e., by sending electrical current into the angular gyrus through implanted electrodes) or too little stimulation (e.g., after tissue damage following a stroke) can lead to distortions in your sense of embodiment. These include out-of-body experiences, the feeling that your body has been duplicated, or the feeling that another body is lurking behind your own.[58] Likewise, stimulating the supramarginal gyrus by electrical current leads to a vague feeling of disembodiment—one such patient, G.A., reported that the brain stimulation made her feel as if she was floating away or as if her arm was moving; she also asked "Am I here?"[59]

Similar experiences of disembodiment can be found in meditative states. Jack Kornfield interviewed about 160 yogis who were participating in a long (two-week or three-month) meditation retreat.[60] Some of the meditators[61] reported shifts in body image. Examples included feeling the body dividing in half, a sensation of floating, feeling the body disappear, losing the sense of touch, experiencing the limbs as huge and bulbous, observing the head becoming detached from the torso, or sensing the self leaving the body. It is possible that some of these changes in the sense of embodiment originate in activation or deactivation of the angular gyrus and/or activation of the supramarginal gyrus.

More than half of Kornfield's retreatants also reported spontaneous movements (arms rising involuntarily or flapping, the whole body pulling to one side, spontaneous hand movements, and the like). This can potentially be linked to changes in the Tomasino map as well: Meditation activates the supplementary motor area. The supplementary motor area coordinates movement; meditators may engage it to control their posture. If this activation misfires, an involuntary movement may occur.[62]

This activation of the supplementary motor areas may explain other side effects: This area also routinely provides sensory suppression during motion—that is, while you move a limb, sensations in that limb are disregarded.[63] The reason for this sensory suppression is that otherwise you would be overwhelmed with sensations every time you move a limb—as I type this sentence, for instance, my arms and fingers and shoulders are fiercely and rapidly moving, and if I were acutely aware of all those sensations, I might be very much distracted from my task of molding thoughts into words and sentences. It is possible, then, that the numbness you can experience during meditation—like not being aware of sensations in your hands or no longer realizing where your bottom ends and your cushion starts—have their origin in this activation.

Taking all of Tomasino's map together, three themes emerge—**attention**, **body**, and **self**. These themes also suggest four flavors of experience. That is, meditation is an ongoing pursuit of *control over attention*, with an *increased focus on body sensations*, accompanied by an *increased feeling of disembodiment* and a *quieting down of the storytelling mind.*

I note again that my interpretation of Tomasino's map is a story. Many brain regions do many things, and while this story makes sense (at least to me), it is certainly not the only story one could spin about these results. Also, as we accumulate more and more studies, it is likely that we will need to redraw the contours of this map.

{ 3 }

The Meditating Brain in Action

ATTENTION, BODY, AND SELF

In Chapter 2, I gave an overview of what happens in the body and the brain as you meditate. With regard to the brain, three themes emerged: Changes in attention, changes in body awareness and the sense of embodiment, and changes in the sense of self. In this chapter, I offer a more detailed look at studies that flesh out these three themes in a more dynamic context, that is, as they unfold over the course of a meditation and over the course of a lifetime of meditating.

Theme 1: Paying Attention

Tomasino et al.'s map is static; that is, it provides an insight as to what areas of the brain and what brain networks are active during meditation. Meditation, however, is a dynamic process, where periods of great clarity trade off with episodes of great dryness, and moments of sharp focus are interwoven with interludes of mind-wandering.

ATTENTION AS THE NEURAL SWITCH INTO MEDITATION

What happens when you sit down, close or half-close your eyes, and start meditating? Is there a neural switch, a brain circuit that turns on to propel you into a meditative state?

Klaus Bærentsen and colleagues[1] used a simple but effective procedure to examine this switching process: They asked a group of 31 experienced meditators to do a form of on/off meditation inside the scanner—short alternations of 45 seconds of meditation and 45 seconds of rest. Such short bursts would tell us what happens as meditators sink into the early stages of meditation.

They found three types of effects within those 45-second episodes. (Note that because this is just one study, the regions activated or deactivated do not always correspond to Tomasino et al.'s map.)

First, meditators activated the inferior parietal lobe, which, as we have seen, is a part of the executive control network that has a direct link to the default-mode network. Second, likely as a consequence of this activation, parts of the default-mode network (notably the precuneus and the posterior cingulate) were deactivated. As you may recall, both the precuneus and the posterior cingulate are also part of the narrative self. This suggests that, at the onset of meditation, the chattering narrative self gets actively shushed. A third effect concerned body awareness, in both guises. That is, Bærentsen et al. observed activation in the supplementary motor areas familiar from Tomasino et al.'s map, as well as activation of the primary somato-sensory cortex; both activations likely indicate a sharpening of specific bodily sensations. They also noted the equally familiar deactivation of the angular gyrus (more specifically the temporal parietal junction), indicating an increasing sense of disembodiment.

The nice surprise is that there are no surprises: By and large, these bursts of mini-meditations show the same pattern of results that appear on Tomasino et al.'s map. Attention switches on, the narrative self dims, sensations are played up, and whole-body awareness is turned down. This result suggests that meditation (or, more precisely, focused-attention meditation) really is a state of consciousness, just like sleep or wakefulness is a state of consciousness. By this I mean that meditation, like any other state of consciousness, presents a consistent pattern of coordinated interaction between specific brain systems—it forms what Tomasino et al. call a "meditation network." Another way of saying this is that meditation is a whole package that by its nature implies the four flavors of experience I mentioned at the end of Chapter 2—increased control over attention, increased focus on body sensations, increased global disembodiment, and a quieting down of the storytelling mind. The finding that expert meditators can bring this entire package online within 45 seconds or so, that is, in about 10 or so breaths, suggests that the whole process unfolds rather quickly.

ETERNAL RETURN TO THE BREATH

If you have ever tried to meditate, you know very well that even if you manage to get into the right state of mind within those 10 breaths, it still is far from guaranteed that the rest of the sit is going to be a blissful coasting on an ever-cresting wave of unbroken attention. On the contrary: For most (if not all) of us, attention needs to be reset or sharpened repeatedly over the course of a meditation session.

A study by Wendy Hasenkamp and colleagues[2] illustrates very nicely how attention wavers throughout a session and how the meditating brain copes with those distractions. They put 14 meditators (with, on average, about 1,400 hours of lifetime practice) inside the scanner for 20 minutes and asked them to focus on their breath. Participants were given a button to press as soon as they realized that their mind had wandered.

The researchers took a slice of time of three seconds around the button press as an indicator of the brain state of becoming aware that the mind had drifted off. (The three-second time frame has to do with the way the brain was scanned in this study, that is, in time slices of 1.5 seconds.) They took the three-second slice of time right before the "becoming aware" slice as an indicator of the brain state of mind wandering. The three-second time slice right after the "becoming aware" slice was used as an indicator of the process of shifting back into the meditative state. Finally, they considered the three seconds after that as an indicator of the brain state of sustained attention. Thus the assumption is that there is a cycle: After a period of time of sustained attention, the mind wanders, gets caught in the act, and then attention shifts and you get back on track.

Hasenkamp et al. found that when the meditators' minds wandered, many regions of the default-mode network were activated (the posterior cingulate cortex among them)—as you would expect. The phase of becoming aware mainly showed activation in the anterior insula and the anterior cingulate cortex, regions associated with the salience network. The state of shifting was associated with the executive attention network, here the lateral prefrontal cortex, and with the inferior parietal lobe. The researchers also found activation in the ventromedial cortex. This part of the brain specializes in self-related processing, particularly in emotion regulation (i.e., bringing down the level of emotion after a negative experience). Maybe this activation is related to the experience of letting go of the potentially emotionally grating experience of once again noticing that the mind has run off and then gently, with no hard feelings, bringing it back to where it needs to be. During the sustained attention phase, a part of the prefrontal executive network remained active, but activation in the parietal part of the network activation went back to baseline, maybe because activity in the default-mode network was now sufficiently dampened, and so the parietal meditation switch was no longer needed.

One intriguing finding was how often this cycle repeated, even within this well-trained group of yogis. On average, meditators pressed the button 15.5 times over the course of 20 minutes, that is, once every 80 seconds, or once every 15 breaths or so. (It remains to be seen if this estimate of what happens in the scanner is a reasonable estimate of what happens on the cushion. It is possible that sitting upright on your own well-worn meditation cushion in your usual meditation spot helps with concentration. On the other hand, it is also possible that being watched inside the scanner—brain and all—brings out the best in these veterans.) Equally intriguing is the finding that how often people pressed the button was not significantly related to meditation expertise.

It is clear, then, that during actual meditation there is some cycling back and forth between the attention systems and the default-mode network. I was able to find three other studies that looked at couplings between the default-mode networks and the attention networks during meditation, compared to the couplings when participants are waiting in the scanner, asked to just rest.[3] Each of these studies found a tighter coupling between at least some regions of the default-mode network and at least one of the attention networks during meditation. That suggests that meditators stay on task while meditating: When the default-mode network is active—when the mind strays from the object of its focus—the attention system notices, clamps down, and corrects.[4] As we've seen, while people wait and rest in the scanner, the mind likely goes off as well, but the relative uncoupling during rest suggests that distraction just happens and that people let it be. The tighter coupling during meditation reinforces the main point of Hasenkamp et al.'s study, namely that focused-attention meditation really is a dynamic process, a series of predictable cycles that occurs in a predictable manner.

The main conclusion here is that meditation is a very dynamic process—a cycle of setting a goal, drifting away from that goal, noticing the drift, and then returning to the goal, over and over again. Over the course of their 1,400 hours of lifetime experience, Hasenkamp et al.'s meditators must have gone through about 63,000 of such cycles: 63,000 times of noticing they were off the breath, 63,000 times of returning to the breath, and 63,000 times of getting lost again. That is a lot of drifting off focus and a lot of gentle correction.

I must admit that, as I write this, after my own accumulated 1,700 (and a few) hours, I still find this simple fact astounding: You set yourself an exceedingly simple goal ("focus," "be quiet," "be here and now"), and yet, almost immediately, the mind veers away. Hasenkamp et al.'s data suggest that the essential goal of this simple form of meditation is an unrealistic one: Every time you sit, you set yourself up for failure, in a sense—it's highly unlikely that you will be focused, on task, here-and-now for very long. Yet this "failure" might actually be helpful. That is, perhaps it is exactly the repeated fumbles and their consequences, the gently tugging the mind by its sleeves and setting it back on its course, from which it will then invariably wander, and doing this over and over again that is one of the crucial aspects of this practice—it may be this cycling that builds up trait mindfulness.

QUIETING THE MIND

All of this could lead us to conclude that quieting the mind is hard work. But that would be wrong, as very nice recent work by Kathleen Garrison and colleagues[5] shows.

All of the studies we have looked at so far are still probing meditation from the outside—we are inferring what the mind is doing from what the brain is telling us, and this is risky business. Garrison and colleagues wanted to know how brain activation relates to life as seen from the inside. What does it actually *feel* like to sit down (or lay down, in the case of an fMRI study), focus your attention, and quiet down, and exactly how is brain activation related to that experience?

Garrison asked 10 seasoned meditators (with, on average, 10,000 hours of practice, collected over about 18 years) to meditate in the scanner for short bouts of a minute each.[6] After each bout, they were asked to describe their meditation experience.

Here's the crux: While the volunteers were meditating, the researchers monitored activation in the meditators' posterior cingulate cortex (PCC). As we have seen, the PCC is a central part of the default-mode network, which is activated during self-related thinking—it is part of the circuitry of the narrative self, the self-as-story. This makes it a good indicator of whether the mind is drifting away from the actual focus of meditation.[7] The researchers were able to capture activation in the PCC as it unfolded; they turned this activation into a real-time graph—showing activation up, in red, and deactivation down, in blue, with a new bar popping up every two seconds. Given that the BOLD response (the rushing of blood to the place where it is needed) is sluggish, this isn't really real time: The graph lags behind by a few seconds, but it is close.

Then they had some fun with this.

In the first bout of meditation, participants were simply asked to concentrate on their breath. In the second bout, they were shown an example of a real-time PCC graph (not their own). They were asked to use this graph as the object of their meditation, paying attention to it as they would to any other object of concentration. In the third bout, they were shown the real-time feedback graph of their own PCC activation and deactivation and asked to use this graph as the object of meditation. They were also told that this graph reflected activation in "a particular region of their brain" and that there was a two- to four-second delay involved. Next, they were given three more bouts with the feedback graph and asked to "use their mind to make the graph go blue." To conclude, they were given three final bouts with the feedback graph and asked to "use their mind to make the graph go red."

The researchers wrote down the participants' experiences. There were a total of 404 reported experiences. These were sorted into eight broader categories, forming four pairs of opposites: (a) concentration (experiences of focus, focus on the breath, and clarity) versus (b) distraction (muddled experiences); (c) observing sensory experiences (experiences of physical sensations, engagement with what they saw, heard or mentally experienced) versus (d) interpreting (self-related thinking, deliberating, engaging with memories); (e) not "efforting" (not trying: experiences of open awareness, calm, and acceptance) versus "efforting" (trying to change the experience); and (g) contentment (experiences of pleasure and equanimity) versus (h) discontentment (displeasure, restlessness, discomfort, negative emotions, and the like). These eight categories were then reduced to four: undistracted awareness (concentration and observing sensory experience) versus distracted awareness (distraction and interpreting) and effortless doing (not "efforting" and contentment) versus controlling ("efforting" and discontentment).

These opposites in experience also played out as opposites at the level of the brain. The first element of each pair of opposites (tending toward concentration and letting go) was associated with the graph turning blue—PCC deactivation. The second element of each pair of opposites (tending toward distraction and controlling) was associated with the graph turning red—PCC activation. Experiences that made the graph turn red include[8]: "I worried that I wasn't using the graph as an object of meditation, so I tried, like, to look at it harder or somehow pay attention more to it' (this is "efforting"), or "I began by thinking about a variety of things that need to be done, emails that need to be sent, things that I have not done in a timely fashion, that type of thing" (interpreting). Experiences that turned the graph blue include "Very smooth. It was very easy to concentrate" and "a concentrated meditation this time" (concentration) or "I maintained primary awareness on the full range of experience, including, just, awareness of the body and various touch points, the breath moving throughout the body, the sound being integrated into that sort of, sort of fuller awareness while watching the colors with relative ease . . . body awareness" (observing) and "The red bars correspond to times when I was trying to either force the experience or trying to think about, thinking about stuff in general, thinking about making [the graph] blue. And then when I could let it go, [the graph] turned blue" (effortless doing).

In many ways, these results confirm what we already know: Activation of the default-mode network is related to activating the narrative self and to spinning stories—to interpreting the experience, to deliberating, and to being distracted—and deactivation results in the opposite—a sense of concentration and a tendency to simply (and calmly) observe.

What is new here is that this deactivation of the PCC is not an effortful process. Although we know from Tomasino et al.'s map that meditation activates both the salience and the executive network, Garrison et al.'s results show that "efforting"—trying your best, working hard—isn't what quiets the mind. On the contrary, trying hard really gets the PCC going, whereas the stripping away of effort, the effortless doing, the relaxing, the letting go is what settles the mind into the meditative groove. The act of mere observing might be especially important here—what Garrison et al. call the mindset "of not being pushed, pulled, or lost in mental content, feelings, or thoughts as they arise." Meditators in that study described this as "letting things flow by" or "observing thinking."

This is an interesting paradox: Trying too hard to meditate will likely lead to PCC activation and hence distraction and unease, whereas not trying and relaxing into the experience is likely to lead to PCC deactivation and hence contentment and concentration. One of Garrison et al.'s graphs that went quickest and most deeply in the blue deactivation territory was the graph of a meditator who described the episode as: "I noticed that the more I relaxed and stopped trying to do anything, the bluer it went." This seems valuable advice for any meditator: The quality of attention in meditation should be gentle, not forceful. This is, in fact, advice that meditation teachers often give.

One aspect of the results that is particularly encouraging for meditators is that PCC deactivation is associated with feelings of contentment, equanimity, and pleasure. PCC activation, on the contrary, seems to be associated with displeasure. This is encouraging because it suggests that meditation has a direct emotional feedback mechanism built right in: If it brings you calm and peace, you're doing it right; if it feels effortful and ill-fitting, you are probably doing it wrong. Thus one further piece of advice for the new meditator is to lean in the direction of delight in the experience. Again, this advice isn't particularly new. (The caveat is that the meditators in this study were highly practiced—the mileage of novices might vary.)

Finally, I should note that the meditators in this study succeeded very well in the final two tasks, namely to meditate themselves into the red or the blue zone of PCC activation and deactivation. Thus meditators can use biofeedback to guide their experiences. Of course, few of us have an MRI scanner in our basement, so this knowledge is of little practical use. What is useful, though, is that the meditators learned to couple the biofeedback to their states of mind; after you've done that, it might suffice to be guided by your inner experiences. Specifically, some noted the relationship between turning the graph blue and the direct feeling of relaxation, as the quotes in the previous paragraphs show. Another technique was to connect directly to the sensory experience from an observer point of view: "I maintained primary awareness on the full range of experience, including, just, awareness of the body and various touch points, the breath moving throughout the body, the sound being integrated into that sort of, sort of fuller awareness while watching the colors with relative ease . . . body awareness."

DEPTH OF MEDITATION

Although many meditation teachers sternly warn us against doing this, many of us do evaluate our meditation experiences: This was a good sit; this was a not-so-good-sit (and maybe once in a while we have an excellent sit). Is there anything to this feeling? Can the brain show us what is better and deeper about better and deeper sits?

Danny Wang and colleagues[9] asked 10 long-term meditators (with, on average, about 20,000 hours of Kundalini yoga experience) to meditate for 24 minutes inside the scanner. The meditations were of the focused-attention type. In one practice, called Kirtan Kriya, they repeated a short four-syllable mantra while counting the syllables on their fingers; in the other, Shabad Kriya, they focused on the breath while repeating the mantra with each exhale. The researchers found that meditations that were rated as deeper and more intense were associated with lower activation in the medial prefrontal cortex and in the anterior cingulate cortex—areas that, as we have seen, deal with self-reference and the salience network. Thus stronger meditations tended to be associated with less self-centeredness and with a less active inner monitor. The study cannot tell us, however, what the direction of influence is. It might be the case that we consider meditations to be deep when we manage to set our selves and our fault-finding ways aside. Or it might be the case that our self and the little check-marker in our head is less active in deep meditation because everything runs along smoothly and there is less fault to find.

An additional finding in this study was that deeper meditations tended to be associated with activations in the left forebrain, in areas that are known to be associated with positive mood.[10] Again, it isn't clear from these results whether deeper sits make us happier or whether feeling happier during a sit makes us think the meditation is deeper. Kornfield[11] also noted in his survey of retreatants that bliss is almost always associated with deep concentration of the mind.

ATTENTION IN OPEN-MONITORING MEDITATION

The type of meditation that has been studied most in the scanner is focused-attention meditation; all of the studies I mentioned in this chapter so far are of that variety. We saw that this type of meditation involves an intricate dance between, on the one hand, the salience system and the executive system, which pull you toward the object of the focus of attention, and, on the other hand, the default-mode network, which seduces you into zoning out.

In an overview paper on how attention is regulated and monitored in the two main types of meditation—focused attention and open monitoring—Antoine Lutz and colleagues[12] argue that open monitoring might be different on three counts. First, because open-monitoring meditation is, by definition, not focused on one particular object, there might be reason to assume that the executive system would be less involved. Instead, you might expect more activation in the salience system, which would be probing what is, right here, right now, relevant for your sit. Second, open-monitoring meditation involves the cultivation of awareness of the internal body states, and so you might expect more activation in regions that are concerned with the body, such as the somatosensory cortex. Finally, for some, and in some traditions, open monitoring might involve an attempt at emotion regulation, for instance, by labeling of feelings and emotions when they come up during a sit. This might be reflected in brain activation as well.

All three of these assumptions seem more than reasonable. Unfortunately, there are not yet enough studies that have probed open monitoring to warrant a meta-analysis. We can, however, look at the few existing studies and try to draw some tentative conclusions.

The most interesting studies would be those that directly contrast the focus-attention and the open-monitoring approach to meditation. I could find only two such studies. Sadly, they do not converge on the same conclusion.

The earliest of those two studies, by Antonietta Manna and colleagues,[13] studied eight Buddhist monks from the *Theravāda* tradition, with 15,750 hours of accumulated meditation experience on average. During open monitoring, the left hemisphere, especially the left anterior insula and the left precuneus, was more active than during focused attention. Activation was also higher in midline structures and superior temporal areas—brain regions typically associated with self-awareness. The results suggest that, as Lutz et al. predicted, the salience network (here: the insula) might be more active, and awareness of internal states (here: precuneus, midline, and superior temporal areas) might be turned up as well.

One interesting result not predicted by Lutz et al. is that, unlike what Tomasino et al.'s map shows, the precuneus, typically related to the narrative self, was activated rather than deactivated in the open-monitoring portion of the meditation. Interestingly, activation in the language-related areas of the brain was not higher during open monitoring, suggesting that this heightened awareness of one's internal state is not associated with the creation of an actual story involving words (or at least not more so than simply resting or focusing on the breath do).

The second study, by Judson Brewer and colleagues,[14] contrasted focused-attention meditation, open-monitoring meditation, and loving-kindness meditation inside the scanner in a group of 12 practitioners with, on average, about 10,000 hours of practice. They found few differences between open-monitoring and focused-attention practices, but the one difference they did find—lower activation in the superior and medial temporal gyrus—stands in contradiction to the results from Manna and colleagues, who found higher activation in the superior temporal areas.

What to make of these results? The predictions made by Lutz et al. sound reasonable, but it seems that there is little support for them, at least in direct comparisons between focus-attention and open-monitoring meditation. One study provides support for two of the hypotheses; the other does not support any of them and contradicts one earlier finding. The sad conclusion, for now, is that we know all too little about the specifics of the differences between focused attention and open monitoring.

A NOTE ON JOY AND JHANA

Two sections ago, I mentioned bliss.

People who don't meditate sometimes think that meditators simply close their eyes and off they go into the sunset, riding magnificent waves of radiant bliss.

People who meditate know otherwise.

In some ways, of course, an absence of strong positive emotions is to be expected in attention-type meditations. In focused-attention meditation, there is a singular focus—typically on the breath—and when thoughts or emotions pop up, the meditator simply returns to the breath, without judgment and with acceptance. In open-monitoring meditation, you simply observe, without attachment, what comes up. Over time, this leads to equanimity vis-à-vis the original event that provoked the emotion.

There is one Buddhist practice, however, that has the effect of generating joy or bliss from within, without any external cues, at least during some of its stages—*jhana* meditation.[15] *Jhana* meditation is a progression through eight sequential practices or stages, each further deepening the meditator's concentration to the point of losing contact with the senses and hence the outside world. Stages 1 to 3 are associated with extreme bliss and the later stages more with a less ecstatic sense of deep peace and equanimity.

There is alas only a single brain-imaging study on *jhana* meditation, and it includes only a single meditator.[16] This meditator, Leigh Brasington, is, however, a well-known teacher in this field, with 17 years of experience; the authors of the study claim he might be the one and only person in the United States with the requisite proficiency in *jhana* who was willing to participate in the study.

To test the joy hypothesis, the researchers probed the dopamine system. Dopamine is a neurotransmitter (i.e., a chemical messenger in the brain) that is released during pleasant events—your favorite food, sex, good music, money, and drugs are some things that get the dopamine response going. The researchers tapped into two crucial brain regions within the dopamine system, the nucleus accumbens and the medial orbitofrontal cortex. The nucleus accumbens is the basic brain structure from where the dopamine rush originates; the medial orbitofrontal cortex is activated a little later—it is where pleasure registers in awareness.

The results showed that both the nucleus accumbens and the medial orbitofrontal cortex were activated during Stage 2 *jhana* (Stage 1 was not recorded due to a technical difficulty). Interestingly, activation in the nucleus accumbens declined after Stage 2, but the orbitofrontal cortex stayed active until

Stage 4. Thus, even as the dopamine reserves dwindled (as they are wont to do—no high lasts forever), the subjective experience of joy still lingered.

Brasington described his experience quite dramatically—Stage 2 was compared to "opening a birthday gift and getting exactly what you most wished for" and Stage 3 to postcoital bliss. As the researchers point out, however, the activation in the dopamine network wasn't actually all that spectacular. What is most probably happening is that due to the intense concentration during *jhana* meditation, most cortical activity quiets down. In that quiet environment, even a modest reward signal from the nucleus accumbens will be detectable, and it will be felt as much more intense than it really is. Thus training the mind to be quiet might help to inflate simple feelings of contentment into something approaching rapture.

Finally, the astute reader has noticed that neither the nucleus accumbens nor the medial orbitofrontal cortex are part of Tomasino et al.'s map. This underscores again what I mentioned at the beginning of this section: Meditation in its most typical forms is not likely to catapult the meditator into euphoria on a day-by-day basis.

Theme 2: Awareness of the Body and Its Sensations

The focus of meditation manuals and teachers is almost exclusively on how to deploy attention and how to work with emotions. The day-to-day practice of meditation, however, comes with a wide variety of experiences, which often receive a lot less mention in meditation manuals. In this section, I focus on what we know about bodily and sensory experiences during meditation.

I start by mentioning that although most people assume humans have five senses (sight, sound, smell, taste, and touch), in reality we have quite a few more. The list also includes (but is not limited to) proprioception (knowing where your body parts are relative to other body parts), interoception (the sense of the physical condition of your body), thermoception (sense of temperature), equilibrioception (the sense of balance and acceleration), and nociception (awareness of pain), and even, some claim, a sense of time. Not all of these, obviously, have been investigated during meditation.

Earlier I mentioned Kornfield's survey of about 160 meditators who had just finished either a two-week or three-month insight meditation retreat. Kornfield examined the data for "unusual" experiences, and found that most fell into three broad categories: *somatic experiences* (e.g., changes in proprioception and nociception), *visual experiences*, and *mental experiences* (in which Kornfield included experiences such as mood swings, rapture and bliss, changes in the perception of time, and out-of-body experiences). If you're experiencing any of these in your sits and you would like to know whether what you're experiencing is "normal," that is, something many meditators experience, or just a few, you're out of luck: Kornfield refused to provide exact frequency data for most of the experiences. What we do know: 55% of the questionnaires mentioned the somatic experience of "spontaneous movement"; spontaneous alterations of body perception (like a feeling of being switched to slow-motion, a feeling of floating, or a loss of body awareness) were reported "frequently" and so were visual hallucinations, either with the eyes open (this involves seeing color changes in the visual field, perceiving still objects as moving, having your perceptions sharpened or intensified, seeing vibrations in the air, or having LSD-like melting visions) or with the eyes closed (seeing flashes of light, or colors, or more full-flung visions, like beholding the Buddha). Mental experiences were also common: 47% of the reports mention dramatic mood swings (sudden heavy sadness or flatness, fear, anger, sexual fantasies, rapid switching between doubts, bliss, boredom, serenity, joy, etc.), perhaps offset by the rapture and bliss reported by 40% of the two-week and 95% of the three-month meditators.

In the remainder of this section, I concentrate on three items on Kornfield's list that we do know a little about: body awareness experiences, visual hallucinations, and perceptual awareness during meditation (i.e., how much of the world gets through to you); I add what we know about how meditation alters pain perception.

AWARENESS OF THE BODY IN SPACE AND TIME

Changes in body awareness during meditation are not unusual. I assume anyone who has ever sat recognizes that after a few minutes of concentration the body fades somewhat into the background: It becomes a little harder to tell where the bottom ends and the cushion begins; if your hands touch or hold each other, it might become less clear which hand is which, and so on. More extreme examples of changes in body awareness can easily be found—see Kornfield's previously mentioned list.

It is, of course, impossible to link such experiences to whatever is happening inside the brain unless one has a precise account of what the meditator experiences. That is exactly what Aviva Berkovich-Ohana and colleagues[17] set out to examine in a group of 16 *Vipassanā* meditators with, on average, 11,225 hours of meditation practice.[18]

The original intent of the researchers was to examine the perception of time and space during meditation (i.e., where you are in time and where you are in space). Their hypothesis was that this sense of where you are might be intimately linked to your body awareness—a sharper body image would lead to a sharper sense of time and space or vice versa.

The design of the study was quite complicated, but understanding it is worth the trouble, so bear with me. First, instead of waiting until meditators reported time and/or space experiences, the researchers provided the meditators with instructions. A first set of instructions was to "Try to be in the present moment" (let's call this the "now" instruction) and "Try to be here" ("here" instruction)—routine meditation instructions. A second set of instructions was to "Try to be in the near past (in the same place—the lab)" ("then" instruction) or "Try to be elsewhere (at the moment, with the experimenters outside the shielded magnetoencephalography [MEG] room)" ("there" instruction). Finally, the meditators were instructed to "Try to be outside time" ("timelessness" instruction) or "Try not to be in the center of space" ("spacelessness" instruction). Participants cycled through these instructions, taking 90 seconds for each of the six meditations.

This design allowed the researchers to look at a few things these conditions have in common in terms of activation and what sets them apart. First, looking at what the pairs within each instruction have in common gives us an idea of what is overlapping in the brain's representation of space and time. Second, looking at the contrast between the second and the first set of instructions (comparing "then" with "now" and "there" with "here") gives us some idea of what brain regions are involved in memory, imagination, and the like. Third, the contrast between "timelessness" and "now" and between "spacelessness" and "here" tells us something about how the brain perceives timelessness and spacelessness. Here is where the second contrast comes in handy: We want to make sure that the third contrast isn't simply the meditators' imagination going wild, so it would be good to find that the third contrast involves different brain regions than the second contrast.

After the meditation session was over, meditators were interviewed about their experiences. Eight participants reported alterations in the sense of body boundaries. Four of those involved a more diffuse sense of self, that is, the feeling that the self spilled out of the body or that the body itself faded (e.g., "The experience of the body faded. There was a sense of body in the background, not in front of consciousness" and "a pleasant dissolution, something liquid-like"). For three participants, the body disappeared altogether (e.g., "The body as physical image was absent. There was a sense of open space without the bodily dimension" and "There was no awareness to bodily and self boundaries"). One participant reported an out-of-body experience ("I kept entering and leaving my body. Outside the body I felt short and small, like a little child, I shrank."). Thus, even though the instructions did not emphasize the body or its boundaries in any way, the meditators' attempts at meditating outside time or space had the effect of loosening the sense of body boundaries in half of them.

The contrast between "then" versus "now" and "there" versus "here" showed overlap in activation in the part of the default-mode network typically associated with mental time travel (i.e., reminiscing about the past or planning the future), as it should. Interestingly, these regions were not the ones that were activated when participants were meditating timelessly or spacelessly. Meditating timelessly involved activation not only in brain regions typically associated with time (right posterior parietal cortex) but also in regions typically associated with body awareness (right insula, right somatosensory, and medial posterior cingulate cortex). Likewise, spaceless meditation did not only involve regions associated with spatial processing (bilateral temporal gyrus, left thalamus, right postcentral gyrus, medial frontal gyrus, bilateral frontal cortices, and right parietal lobule) but also regions typically involved with interoception (bilateral posterior cingulated cortex and right insula). Thus meditators who try to meditate spacelessly and timelessly also deactivate some of the brain areas associated with situating the *body* in space and time, which might result in a feeling of disembodiment, as the reports noted in the previous paragraph suggest.

This result was confirmed in another analysis. Here, the researchers split up the participants in two groups: One group, about half of the participants, consisted of those meditators who reported a change in the sense of both space and time (e.g., "The center of space became endless, without a reference point. . . . Time was less relevant"); the other group consisted of the rest of the participants, that is, meditators who either reported a regular experience of both space and time (e.g., "The mind was in the present moment") or a change in either the sense of time or space, but not both (e.g., "A sense of expansion, something open and wide"). The first group showed lower activation in the temporal parietal junction and the insula and increased activity in the cerebellum. As we discussed in the previous chapter, these regions are associated with embodiment.[19] So what distinguishes people who report more timeless and spaceless awareness in meditation from those who do not is not any brain region that has to do with time perception or spatial awareness per se. Instead, the two groups differ in activation in brain areas that are associated with a sense of the body.

Taken together, the results from Berkovich-Ohana et al.'s study suggest that in meditation the senses of time, space, and body are intricately interwoven—when the experience of one of those changes, experience of one if not both of the other ones will change as well, for the simple reason that all three share activation in common brain regions. The final set of results cited here suggests that changes in the sense of embodiment might be the driving force. That is, changes in time and space are associated with changes in regions that situate the body in space and time, but when there are no changes in these body awareness regions, there are no changes in the perception of space and time. Thus meditators who are trying to achieve a timeless and/or spaceless state do so (knowingly or unknowingly) by altering the perception of the body—a more diffuse sense of body boundaries may well allow the meditator to feel free from the confines of time and space as well.

VISUAL EXPERIENCES

Another interesting side effect of meditation is the potential presence (in some people and some of the time) of visual experiences of the kind psychologists routinely call "hallucinations." How common or uncommon these are is unknown—Kornfield simply mentions they happen "frequently." My own anecdotal polling of fellow meditators suggests individual differences—some people encounter visual experiences while meditating and other people don't, and both categories of people are surprised to hear of the other's existence.[20]

I hasten to state that "hallucination" is a very strong word, often associated in people's minds with mental illness. Here I simply intend the word's neutral, descriptive meaning in psychologists' lingo: Seeing something that isn't physically there. The examples in Kornfield's study include color changes in the visual field, light flashes, colored lights, fields of great brightness, "a luminous mind," feeling as if someone is shining a spotlight on you or—for those who meditate with eyes open—increased clarity of vision, melting-like visions, or seeing air energies or vibrations. Kornfield also mentions more complex experiences, such as visions of the Buddha, a radiating cross, or—scarier—a hand-sized spider emerging out of the floor. Hallucinations can also occur during walking meditation—seeing sparkles of light while walking at night, for instance.

A more systematic study of these phenomena was undertaken by Jared Lindahl and colleagues.[21] They looked in detail at the experiences of 28 people recruited from Buddhist meditation groups. This was not a random sample: The researchers included only yogis who had ever encountered—to quote their ad—"a meditation-related experience that was significant, unexpected, challenging, or was associated with physiological or psychological changes." Out of these 28, nine participants, roughly one out of three, reported seeing lights or other forms of luminous experiences; these started occurring, on average, five years into their meditation practice.

The experiences fell into two types. The first type concerned distinct light forms. A typical example is "Sometimes there were, oftentimes just a white spot, sometimes multiple white spots. Sometimes the spots, or 'little stars' as I called them, would float together in a wave, like a group of birds migrating." The second type of experience concerned patterns and fuzzy visual experiences, commonly described by the practitioners in this study as shimmering light, a pixilation of space, or a brightening of the visual field. A typical account is "Even with my eyes closed, there would be a lot of light in the visual field. Diffuse, but bright. . . . When I let go, I was totally enveloped inside this light. . . . I was seeing colors and lights and all kinds of things going on . . . Blue, purple, red" and "There was often a curtain, this internal curtain of light."

Before I turn to Lindahl's take on these phenomena, it might be good to note how meditation teachers react to such experiences. Lindahl gives a long overview of these reactions. In some traditions, visual experiences are viewed as positive, that is, as signals of progress on the meditative path. In some forms of *Theravāda* Buddhism,[22] the first type of visual experience—spots of light—is often called a *nimitta*, or "sign." Experiencing a *nimitta* is seen as an indication that your practice is progressing to a stage where deep concentration becomes possible. In the Tibetan tradition, both types of luminous experience—spots and fuzzy lights—are likewise sometimes interpreted as signs of progress—indications that the practitioner is making contact with her own clear and luminous mind.[23] Other traditions, however, consider these experiences as side effects that can lead the meditator astray, making her believe she is further along on the path than she actually is. This idea is expressed clearest in contemporary forms of *Theravāda* Buddhism in Burma[24] or in the Zen tradition.[25] Still other traditions, like some Western forms of *Theravāda*[26] or the Tibetan Dzogchen tradition,[27] encourage the meditator to read and sometimes even manipulate these experiences in particular ways to advance her practice. For instance, Ajahn Brahm suggests that meditators first learn to recognize the *nimitta* and then try to "shine it up" or make it more radiant by focusing on its center, to finally stabilize it. If the meditator is able to stay with the *nimitta* with a one-pointed mind, she will eventually enter the *jhana* state.

What can science tell us about those light experiences?

To answer this question, we must take two characteristics of these visions into account. The first is that these hallucinations don't occur early on in practice—they only appear after some expertise in meditation has been developed. Half of the visions reported in the Lindahl et al. study also debuted during retreats, that is, during periods of extensive, concentrated practice. Second, the visions described by the meditators in the Lindahl et al. study are all what psychologists call "simple" hallucinations. This is important because both characteristics rule out one trivial explanation, namely that the meditators are having hypnagogic hallucinations—that is, the kind of visions you have when you are falling asleep. If the yogis were falling asleep, the visions would to be more akin to dreams—multisensory (typically, hearing things as well as seeing things), widescreen, without insight in their nature, and uncontrollable.

Lindahl et al. note that in nonmeditators such simple hallucinations occur after sensory loss, for instance when people are submitted to extended periods of isolation, silence, darkness, and immobility, or when they are living in a very monotonous environment—like an isolation cell in a prison. Visual impairment can be a cause as well (e.g., older adults with very poor vision can develop hallucinations; the so-called Charles Bonnet Syndrome). In fact, it doesn't take long for sensory loss–driven hallucinations to occur—15 minutes in a fully darkened room that completely dampens sound typically does the trick.[28] You likely don't have access to an anechoic chamber (aka, "dead room"), but you can mimic the effect easily by blindfolding yourself and blasting a white noise app through your headphones loud enough to drown out external sounds; half an hour of this often leads to (sometimes remarkably detailed) visual hallucinations. The bonus is that you are likely to also experience auditory hallucinations.[29]

Sensory-loss-driven hallucinations are associated with activation in the occipital cortex, the seat of the early visual system located in the back of the brain.[30] It is this activity that appears to cause the hallucinations, rather than the other way around: In an fMRI study with Charles-Bonnet patients, activation started ramping up in the visual system before the patient reported the hallucination.[31] In the same study, the researchers also found a logical connection between the content of the hallucination and the brain region that was activated: A participant who reported seeing faces showed activation in the left middle fusiform gyrus, an area associated with face perception; patients seeing featureless colors showed activation in V4, a region crucially involved in processing color, and so on.

What is then likely happening is that lack of input into the sensory regions of the brain leads to spontaneous firing of neurons within those regions through a mechanism called homeostatic plasticity—adjustments to keep the activity levels within neuronal circuits stable. This can lead to two things. One is lowering of the firing threshold of the particular brain region, which is a fancy way of saying that the region will be easier to stimulate (even a little light that falls on your closed eyelids might look very bright and colorful); the other is that the neuronal circuit starts firing above threshold even in the absence of an external stimulus (i.e., you hallucinate).

Meditation is a close cousin to sensory deprivation. You sit as immobile as you can in a quiet room, alone or with no social interaction, often with the lights dimmed, and you either fix your gaze on a point on the wall or floor or close your eyes altogether. Although this isn't an actual situation of sensory deprivation (sounds and smells gets through, and, for those who do not close their eyes, vision remains engaged), it is clearly one of diminished input.

Lindahl et al. speculate that a keen attentional focus, engaged with something very monotonous and undifferentiated like the breath at the exclusion of everything else, might be the additional crucial element to bring the meditator into a zone of deprivation. This might explain why meditation-based hallucinations typically appear after only a few years of practice and why they are more likely to surface during retreats—the attentional focus, with its active clamping down of all that is not the immediate object of attention, needs to be strong enough to create the effect. In line with this conjecture, seven out of nine practitioners in the Lindahl et al. study who mentioned light experiences connected the arising of these experiences with a period of enhanced concentration.

All of this, for now, remains largely speculative. There are no fMRI studies of hallucinations during meditation. There is, however, one EEG study,[32] which found that EEG for two meditators who reported light experiences during a testing session showed strong alpha blocking, likely a sign of the brain clamping down on external and internal input—as Lindahl et al. speculated.

So which of the three Buddhist explanations for these phenomena is correct? Intriguingly, Lindahl et al.'s study suggests that all three have their merit.

First, the finding that enhanced attention might be necessary for the hallucinations to occur fits well with traditions that claim that such hallucinations are a sign of progress: *Nimitta* or the luminous mind appear after a long build-up of attentional muscle; they can thus herald an advance in singularity of focus. Note here that although the results suggest that these visions are signposts for progress in attention, the inverse is not necessarily true. That is, individuals who never experience such visions are not necessarily *not* making progress—there is no reason why attentional focus should always and automatically lead to visual experiences.

Second, the traditions that claim that the *nimitta* are nothing more than side effects are correct too: The hallucinations don't seem to play any direct crucial role in progress in any other aspect of meditation.

Third, the traditions that suggest that the *nimitta* can be used as guidance for increasing concentration may also be correct. The EEG study suggests that the presence of *nimitta* may be indicative of the strength of attention in the moment. Developing the ability to maintain or stabilize the *nimitta* may then be a very good feedback mechanism for further concentration training. One study on sensory deprivation[33] found that participants often tried to play with their hallucinations and that those research subjects who were able to shift their attention to different aspects of the experience (e.g., fluctuate between what they thought they were hearing in a sea of white noise and their internal body states) or who were able to zoom in on the hallucinations were also the ones who reported such perceptions more frequently. Thus the ability to shift attention or zoom in on the visions might be a hallmark of increased concentration and may be exactly what is needed to bring you to the threshold of absorption, and maybe beyond, as advocates of the third position claim.

NOISE AND SOUNDS: NOW YOU HEAR IT, NOW YOU DON'T

Meditation is often done with the eyes closed or half-closed. It is, of course, impossible to close your ears, and sounds will, almost by definition, intrude. (A possible exception concerns the deeper stages of meditative absorption, where the claim is that all senses, except the sense of mind, fall away.)[34]

From what we have seen so far, we might formulate two expectations for focused-attention meditation. One is the general expectation that focusing attention simply works, and so sounds and noise might become less noticeable. The other expectation is that the occasional paradoxical episode will occur as well, where deep concentration leads to hypersensitivity to sounds, just like visual isolation leads to lower visual thresholds. Fainter noises will then be perceived more clearly, and ordinary noises may sound louder. When my wife and I sit at home, sometimes one or the other of our cats likes to sit with us. Being a cat, her initial curling-up session might abruptly erupt into a fur-licking fest. When this happens, I often misjudge the cat as being much closer by than she actually is. In meditation halls, it can sometimes seem as if your neighbor is breathing right into your ear. And I once witnessed an otherwise unflappable long-term practitioner of *Vipassanā* meditation get up quite resolutely 10 minutes into a sitting, tear our newly acquired clock off the wall, and throw it into the hallway, after which he returned, serenity re-embodied, back to his cushion.

During open-monitoring meditation, in contrast, the practitioner is expected to observe his internal and external environment, and so we might expect that sounds do get through and may even be noticed more quickly or hit with higher intensity.

The literature on auditory perception and meditation is large; much of that literature investigates the effects of Transcendental Meditation®. Most studies ask the participants to meditate and then present them with sounds during or right after the meditation period—clicks at regular or irregular intervals, most often—and measure how the brain processes these sounds. Most of the work has been done using EEG.

When we look at the literature, however, the picture isn't clear at all.[35] For the six studies that examined open-monitoring meditation, the evidence is mixed: Three studies find enhancement (i.e., stimuli are processed better or faster), one finds no difference, and two find suppression (i.e., stimuli are processed less well or slower). For the nine studies that examined focused-attention meditation, the results suggest maybe a suppression effect: One study finds enhancement, three find no difference, and five find evidence for suppression. It is precarious to draw general conclusions from such diverse findings.

Here I highlight two results from this group of studies that might give you a sense of the complexity of the literature. One comes from the McEvoy et al. paper. In this study, the researchers tested five expert practitioners of Transcendental Meditation®. They examined how the brain reacted to very short clicks (lasting 1 millisecond, that is, 1/1000th of a second), presented at 20 clicks/second immediately before and after meditation. The researchers recorded EEG in the brainstem; this EEG measured very early processing (i.e., the brainwaves started between 5.5 and 9 milliseconds after the stimulus occurred, depending on how loud the click was)—way before the sound signal reached the cortex and stood even a chance of being represented in awareness.

It turned out that the brainstem reacted differently based on the intensity of the clicks. When clicks were presented quietly (at 5 to 40 decibels, the sound level of, at most, a whisper), there were no differences in processing before and after meditation. Between 40 and 50 decibels (about the level of ambient urban noise or a very quiet conversation), the brainstem response was slightly delayed after meditation, suggesting that sounds at these levels are processed less well during meditation. At 60 to 70 decibels, however (the sound level of a normal conversation or of background music), there was a speed-up after meditation, suggesting that meditators are more sensitive to these sound levels during meditation than before meditation.

So, in this study, meditators were able to shut out (at least to some extent) sounds that occurred at the levels typical for a quiet meditation hall (from a whisper to birdsong and ambient traffic noise), but they became hypersensitive to sound levels just a little louder than that—the level of casual conversation. (Maybe this explains why nothing grates meditators more than someone having a conversation right outside the meditation room.)

In the second study, Cahn and colleagues tested 16 expert *Vipassanā* meditators (with, on average, 20 years of experience). They compared EEG recorded during a meditation period with EEG recorded during a period of mind-wandering. During the last four minutes of either meditation or mind-wandering, the researchers played a series of 250 sound stimuli to their volunteers, one per second; the subjects were asked simply to continue what they were doing and ignore the sounds. There were three types of sounds: a low sound, a high sound, and a burst of white noise; the high sound was played 80% of the time and the high sound and the white noise each 10% of the time.

Why the 80% versus 10%? When you repeat the same stimulus over and over, the brain tends to tune it out—a process called habituation. A good example is the ticking of a clock: After a while, the sound of the ticking fades away in your mind, and finally it just slips out of awareness altogether. (This example also shows that habituation is fragile. When attention turns to the clock again, the opposite occurs—the clock now seems louder and more obnoxious than ever before: sensitization.) In the Cahn et al. study, the high tones should have led to habituation, because they were presented very frequently. That did indeed happen for the mind-wandering condition, but it did not for the meditation condition. (This is likely what happened to my clock-throwing friend: The ticking unfortunately failed to habituate.) In the mind-wandering condition, the brain reacted differently to the infrequent sounds (the low tones and the white noise) than to the frequent sound (the high tone), as it should. In the meditation condition, however, the brain did not react differently to the two types of sound.

All of this suggests that, while you meditate, you take in every sound as it presents itself, every moment anew, as if the moments that came before never were—truly engaging with each moment and each event as it arises and passes.

Finally, I would be amiss not to mention one rather spectacular study that demonstrates quite dramatically how far a truly exceptional meditator can go in locking out distractions. In this study, by Bob Levenson, Paul Ekman, and Matthieu Ricard,[36] the two first authors tested the third author, a French monk who, at the time of the study, had been practicing in the Tibetan tradition for more than 30 years. They subjected him to what the paper describes as "a 115 decibels, 100 milliseconds acoustic stimulus." This short burst of noise was meant to sound like a gunshot; 115 decibels is about the noise level of a rock concert, of a bass drum being hit, or of sandblasting (it falls short of the sound level of a real gunshot, which is around 150 to 165 decibels). The idea was to provoke what is called, unsurprisingly, the startle reflex: You jump up, and your parasympathetic nervous system goes wild—your heart rate and blood pressure go up, you breathe more rapidly, and you start to sweat.

There were four conditions in this experiment. The first was an open-presence meditation, in which Ricard went into a state of open monitoring that the paper describes as "very vast, clear, vivid, lucid and fully resting in the moment." After Ricard indicated that he had reached this state, there was a 60-second waiting period, and then a 20-second countdown, at the end of which the fake gunshot sound was blasted from loudspeakers located right behind the monk's head. In the second condition, Ricard first went into a state of focused attention, with his "mind gathered into a point." After he indicated that he had reached this state, the same waiting period-then-countdown-then-blast scenario followed. In the third condition, the same scenario was followed after Ricard entered a state of distraction—thinking about a particular incident from the past. Finally, there was an "unanticipated" startle condition: Ricard was simply blasted with the noise, unannounced.

The researchers measured the strength of Ricard's startle reflex by polygraph (which records automatic physiological responses such as heart rate and skin conductance) and by examining his facial expression. During the study, Ricard was seated on a chair on casters, which had a motion detector attached—yet another way of measuring startle.

Before anything else, the researchers compared Ricard's unanticipated startle response to that of other people of his age and found that Ricard had a perfectly normal startle response.

The meditation results showed that both meditation techniques generally led to much less of a startle response than distraction did, with open monitoring generally yielding less of a response than focused attention. This is remarkable because typically when research volunteers are asked to suppress their startle reflex, this actually leads to a larger response—bracing yourself is counterproductive. Meditation works differently: It is neither a pushing away, as when you are asked to suppress, nor a looking (or hearing) away, as in the distraction condition. Rather, it is a way of being with what happens when it happens. Ricard's own description of his experience during open monitoring was that he was fully in the present moment and the fake gunshot was just one more of those present moments—in a way, there was nothing to be startled about. In the focused-attention condition, Ricard reported being fixed on the incoming event and thus a little more outside the present moment, not resting in a state of no expectation but more in a state in between open acceptance and distraction. This might explain why the startle response was a little more outspoken in focused attention than in open monitoring.

PAIN IN MEDITATION

Pain is one of the certainties in life. It is also one of the certainties in meditation: Almost every meditator who goes through longer retreats will have to deal with a significant amount of pain in her joints or back sooner or later. Interestingly, meditation itself provides some remedy for the pain it provokes.

I was able to find seven relevant papers.[37] In all of these studies, meditators were presented with painful stimuli that were carefully controlled by the researchers. This involved things like hot patches applied to the skin (a typical value is 48°C, or 118°F, for a few seconds), low-level electric shocks (below 400 mA, typically lasting for a few seconds), or laser stimulation (supposed to imitate a needle prick). In most of the studies, the painful stimulus was presented during meditation; in a few, the stimulus occurred right after a meditation session. Some studies compared meditators with nonmeditators; some compared meditation states with various nonmeditative conditions.

The main conclusion is that meditation makes painful experiences less unpleasant—this was found in all five studies that included this measure. Interestingly, that does not mean that the pain is necessarily felt less sharply: In three of the seven studies, meditators rated the pain just as intense during meditation as outside of meditation; the other four found a decrease in intensity ratings. This suggests that the main effect of the meditative experience on pain is not that it removes or dulls the ache. Rather, meditation makes the experience a tad more bearable.

Why is that?

One reason meditation could make pain more tolerable is the parasympathetic response associated with meditation—the calming of the body.[38] The evidence here is mixed: One study[39] found that all of the changes in the meditators' reports of pain intensity and unpleasantness could be explained by the slowing down of breathing rate; another[40] found that meditation decreased pain intensity ratings but simple relaxation did not.

A second potential mechanism is distraction. You are now focusing your attention elsewhere—like on the breath. One finding that suggests that this might be the case is a study by Fadel Zeidan and colleagues—they found that occupying participants' minds by having them work on a simple math problem (counting backward by sevens, starting from 1,000) lowered pain ratings as well, although not as much as meditation does.

Another possible piece of evidence for the meditation-as-distraction view comes from a study on a yoga master who claims he is unable to feel pain during meditation by "concentrating on not feeling pain."[41] The man is clearly not all talk—he likes to demonstrate his insensitivity to pain by sticking needles into his tongue and cheek. The researchers applied laser stimulation to one of the yogi's hands or feet at unpredictable points in time. The yogi reported no pain during meditation but did indicate pain while not meditating. Brain imaging confirmed this report: During meditation, there was little or no increase in activation in regions of the brain that are typically associated with the intensity of pain perception (the thalamus, the somatosensory cortex).

A third potential mechanism is the nonjudgmental, accepting nature of meditation—remember Kabat-Zinn's definition of mindfulness?—especially in its open-monitoring form. This mindful attention can come in a number of flavors.

One is to direct your attention carefully to the actual sensations involved in the experience. In support of this hypothesis, Tim Gard and colleagues found that painful stimulation during meditation activated the posterior insula and the secondary somatosensory cortex. These are brain regions typically associated with pain intensity—the higher the activation, the sharper the pain. But Gard et al. found the actual opposite: Meditators with higher activation in these pain regions rated their pain as less intense. The best explanation is that pain feels less painful when you carefully zoom in on the exact nature of the experience—what it actually feels like moment to moment—rather than labeling it as "pain" and sticking it into the "unpleasant" category.

A second form of nonjudgmental attention is to let go, that is, to disengage the thinking mind and to give up control—to just be with the pain rather than try to influence it. In support of this hypothesis, Gard et al. found that meditators deactivated part of the prefrontal control system of the brain during painful stimulation.

A third way to be mindful with pain is to dampen (or maybe even completely abandon) your usual emotional response to pain. You could reassess the situation and realize "that all components of the experience of pain are merely mental events, and thus do not necessarily need to be acted upon,"[42] This type of reexamination is typically the task of part of the salience network, notably the dorsal anterior cingulate cortex and the anterior insula. Indeed, two studies[43] reported an increase of activation in these brain regions during painful stimulation.

These three mechanisms, of course, aren't incompatible with each other—some may be more at play in some studies, some may be more active in some people than in others, and you can even apply more than one of them at the same time.

On a practical note, this leaves meditators with a nice bag of relatively simple tricks to deal with unavoidable pain: You can focus your attention elsewhere, for instance on the breath; you can get attuned to and relish in the relaxing effects of meditation; or you can take an attitude of openness and acceptance toward the true reality of the experience of the pain as it unfolds, moment by moment.

Theme 3: The Self

THE SELF-AS-STORY AND THE SELF-OF-MOMENTARY-AWARENESS

Earlier I discussed changes in attention and in bodily awareness. This section deals with the third aspect of Tomasino et al.'s map, namely the self. Before I review the studies on how meditation changes the experience of self, I briefly discuss how psychologists see the self (or, rather, the sense or experience of self) and how the brain implements it.

What constitutes the self is still a matter of great psychological and philosophical debate.[44] As I briefly discussed in Chapter 2, most psychologists and neuroscientists make a distinction between, on the one hand, the narrative self, that is, the self-as-story, and, on the other, the core self or minimal self, that is, the self-of-momentary-awareness. One difference is that the narrative self extends over time—it has a past, it lives a present, and it projects itself into a future. The core self does not—it just is, right here, right now.

The narrative self is the aspect of the self that is being interrogated at parties ("So, tell me about yourself," and we know what is expected: You talk about your job, your kids, your spouse, your hobbies, and your recent vacation); it is also the self you consult when you make life decisions ("Should I take that job offer?"—and off you go, dreaming up scenarios, referring to your past experiences, and imagining yourself in new surroundings). The narrative self is crucial in your sense of who you are: It anchors you in your relationships with the world and the people around you, and it connects you with your past and future selves. We can see this, for instance, in people where this sense of self starts to dissolve, as in Alzheimer's disease: From the inside, there can be a real sense of being lost; from the outside, you likewise can get the sense that you are losing a loved one who no longer understands her connection to you.

The narrative self is also a story in another sense: It is a fiction—clearly, a useful one—that is no more than a bundle of momentary impressions that are strung together by memory and the imagination (to paraphrase Hume) but that gives us a helpful sense of continuity. The classical example to illustrate this is to look back at a picture of yourself as a child. Are you the same person as that seven-year-old in that little turquoise jumpsuit? The only reason you can affirm that that child is you is by pointing at the continuity that links you to him, but if you were to meet that child, here and now, he would likely not feel like he was "you" at all.

The minimal, living-in-the-moment, core self is more basic. After all else is stripped away, after all my memories have faded and all my plans are forsaken, I likely would still have the sense that there is an "I" here that "I" experience, an entity that is distinct from the rest of the world, that has a vantage point anchored in this particular body that "I" recognize as "my" own and is capable of doing things of its own accord— "I" am typing these words with "my" hands, because "I" think them, and these words are "mine." This self is short-lived; it's a series of transient selves, a process, born as each of its experiences arises and thus born again with each new experience or, rather, with each shift of attention. The narrative self is likely uniquely human, if only because it seems very much tied to language,[45] but the minimal self most probably is not—our dog,[46] who is right now nuzzling my hand, likely has as much a sense of ownership of his body and of agency as I have and of me-not-being-him and him-not-being-me as I do, but it's unlikely he has a complicated story to tell about himself to his dog park buddies.

These two selves are represented in different parts of the brain, as we have seen. The self-of-momentary experience is often seen as located in the thalamus and the brainstem, the somatosensory cortices, and the insula—those parts of the brain that are sensitive to the current state of the body and its interplay with the environment. The self-as-story is associated mostly with activation in the precuneus and the posterior cingulate, regions that are part of the default-mode network. And, as explained already, at a less self-absorbed, maybe more emotional level, this self is associated with activation in the medial prefrontal cortex as well—also part of the default-mode network.

SWITCHING OFF THE NARRATIVE SELF

In a very elegant fMRI study, Norman Farb and colleagues[47] demonstrated that even beginning meditators are capable of turning off the narrative self. They showed participants (half of whom were trained in mindfulness through an eight-week MBSR program; the other half were complete novices) lists of personality traits, one word every second. Half of the words were positive (like "confident") and the other half negative (like "melancholy").

There were two conditions. One was a narrative-focus condition, designed (as the name suggests) to tap the narrative self. In this condition the participants were asked to judge what was occurring in their minds as they were trying to figure out what the words meant to them; they were also explicitly allowed to get caught up in their train of thought. The other condition was an experience-focus condition, designed to tap into the self-of-momentary-awareness. For that condition participants were asked to just sense, without judging, what was occurring in their mind, bodies, and feelings as they read the words, without purpose or goal. If they got distracted by a particular thought or memory, they were asked to gently return to their current experiences.

The narrative-focus condition did indeed yield, as you would expect, activation in the posterior cingulate and the medial prefrontal cortex, as well as in language areas and the hippocampus (a memory structure). In the experience-focus condition, the mindfulness-trained participants showed suppression of the medial prefrontal cortex—in other words, they were deactivating part of the narrative-self network—and an increase in activation in the insula and the secondary somatosensory cortex—areas associated with the self-as-momentary experience. These results confirm that meditators (even with relatively little prior practice) can tune down the narrative self and tune up the experiencing self simply when you ask them to do so.

One very interesting additional and unexpected result was that, in novice meditators, the two selves were correlated—when the self-as-momentary experience was activated, so was the narrative self, and vice versa. This was not the case in the mindfulness-trained meditators: For them, the two systems were decoupled. So, in people who are new to meditating, engaging the narrative self may be an automatic response, a habit. Even a little meditation experience, however, allows people to step out of this habit and free themselves from getting caught up in stories about I-me-mine, at least for the duration of a sit.[48]

One mechanism that makes the decoupling of the narrative and the core self possible could be the time difference in activation of the two types of self. Two studies[49] have shown that when people judge whether a word applies to themselves or someone else, the brain structures that build the self-of-momentary-awareness come online very quickly—after about 150 milliseconds; the narrative self takes about 500 to 800 milliseconds to become operational. Meditators apparently can learn to exploit this gap and stop the activation emanating from the immediate self before it spreads to the narrative self.

This dampening of the narrative self seems to lead to greater happiness in the moment. One study that looked at shifting from a focus on the narrative self to a focus on the self-of-momentary-awareness during meditation showed that this shift was accompanied by a marked decrease of negative and mixed negative/positive emotions.[50] This may be directly related to the deactivation of the medial prefrontal cortex and the posterior cingulate.[51] Thus narrative-self-less meditating may be one way to (at least momentarily) lift the dark clouds of the mind.

FORGETTING THE SELF ALTOGETHER

Astonishingly, it is possible to go further still in meditation and silence even the self-of-momentary-awareness, as demonstrated by a clever study by Yair Dor-Ziderman and colleagues.[52] They tested 12 long-term practitioners of *Vipassanā* in an MEG machine.[53] (This study is part of a larger study, of which the Berkovich-Ohana and colleagues study mentioned earlier—on timelessness and spacelessness—was another subset.)

As in the Berkovich-Ohana et al. study, participants were asked to cycle through different meditation conditions. The first condition was designed to activate the narrative self ("Try to think what characterizes *you*"). The second was a minimal-self condition, designed to tap into the self-of-momentary-awareness ("Try to experience what is happening to *you* at the present moment"). Finally, the third condition was a selfless condition ("Try to experience what is happening at the present moment, when *you are not* in the center"). The hope here was that this last instruction would deactivate both the narrative self and the self-of-momentary-awareness. Immediately after each bout of meditation, the meditators also told the researchers about their experiences and rated the quality and stability of their meditation.

The contrast between the narrative-self and the minimal-self condition showed a reduction in activation in the medial prefrontal cortex, as well as a more global left frontal deactivation. The contrast between the minimal-self and the selfless condition showed an even further decrease in medial prefrontal activation, as well as a reduction in activation in the precuneus and the inferior parietal lobe. We have met both of these regions before—the precuneus as part of the self-referential network and the inferior parietal lobe as a switch to the default-mode network. Additionally, both regions are known to be involved in the feeling of agency (i.e., the feeling that "I" am the one doing this), in discriminating between self and others, and in differentiation between a third-person and a first-person perspective—all functions of the minimal self. The results here then strongly suggest that meditators can indeed dim down the activation in the core self.

When the core self is turned all the way down, what remains should by definition be selfless. What does this feel like?

Three meditators described their experiences as a general relaxation or quieting of body, thought, or experience (examples include: "less judgmental element; less naming of the experience, less verbally" and "very pleasant and relaxed and quiet. . . . devoid of effort"). These were also the meditators with the least amount of meditation experience (note that the smallest number of accumulated hours was 1,290, which is still quite respectable).

Three participants with more accumulated practice described altered experiences of their body, their senses, or a disorientation in space ("Like in a dream. Sensations of all kinds of things flickering" and "as if I took a step back and am looking at myself from the back. I see myself but I am also aware of what is happening around").

Finally, the four most seasoned meditators described experiences without any sense of ownership or agency ("I understood that it was just a sensation, it was not the hand itself, and the sensation was liberated, and so on in other areas. There were jumps of liberation; there was a deep thought that all this was not mine" and "It was emptiness, as if the self fell out of the picture. There was an experience but it had no address, it was not attached to a center or subject. . . . There was no sense of an object there running the show"). This lack-of-ownership experience seems to be closest to what you would assume selflessness would feel like, and it was the only type of experience associated with a decrease in activation in the inferior parietal lobe, as well as in the thalamus. The thalamus is an ancient brain structure that acts as a hub—it receives input from the eyes, ears, and spinal cord and relays that information to the cerebral cortex; it is also implicated in regulating alertness and sleep. Thus, for this very accomplished group of meditators, this specific experience of selflessness was indeed associated with the dimming of brain regions that are associated with a core, minimal self—as self-less as it could possibly get.

In some forms of Buddhism, notably Zen, the self-less experience, labeled *kenshō* or *satori*, is considered the peak experience of the meditative mind, where "the sense of selfhood is dissolved and an 'unattached, self-less, impersonal' awareness remains."[54] The Dor-Ziderman et al. study suggests that the self-less meditators (or should we say meditations?) might have been self-less in almost a literal sense. That is, this meditative state was associated with a stripping away of activation in regions associated with the self, not with increased activation in some other area of the brain. I point this out because previous research on spiritual experiences has suggested that there is an on switch for mystical experiences, sometimes nicknamed the "God spot" or the "God module."[55] Here we find the opposite: There is no selflessness, emptiness, or *kenshō* module—the self-less experience is exactly what it claims to be: the peeling or falling away of the self, the loss first of your own identity, then of identity altogether. It is not the attainment of something new but rather the letting go, the unplugging of your habitual way of viewing the world from the lens of an "I."

On an interesting side note, all participants in the study felt very successful in their endeavor to meditate selflessly, probably because all of them experienced reduced activation in the precuneus and the inferior parietal lobe, both of which may be associated with some change in inner experience. Clearly, however, only the meditators with a tremendous amount of meditation experience succeeded in actually meditating with only minimal stirrings of a sense of self, although the less accomplished meditators were clearly convinced that they succeeded in doing this as well.

What about the Heart Practices?

All of the studies described here pertain to the attention-based practices—focused attention (including *jhana*) and open monitoring.

What about the third type of Buddhist practice—heart practices such as *metta* practice or compassion meditation?

The sad answer is that we don't know much about brain activation during the heart practices. I could only find six papers; between them, they reported results from four different studies. Only one of those studies—the study by Brewer and colleagues we have already encountered—provided an explicit comparison with other types of meditation.

In the first fMRI study on heart practices, Antoine Lutz and colleagues[56] compared novices and expert meditators. The experts (16 in the 2008 study; data from 10 of them were reanalyzed in the 2009 study) had accumulated between 10,000 and 50,000 hours of meditation experience. All had extensive experience with compassion meditation. They meditated inside the scanner, cycling a total of eight times between 3 minutes of compassion meditation[57] and 1.6 minutes of rest. Every 6 to 10 seconds, a sound was played over earphones. The sound could either be neutral (e.g., background noise at a restaurant), positive (e.g., a baby laughing), or negative (e.g., a woman screaming). Participants were simply asked to continue meditating or resting and to ignore the sounds. The researchers, of course, were interested in how the brain reacted to these sounds.

In general, they found that expert meditators activated parts of the default-mode network more than novices did. More specifically, they activated parts of the network that are associated with present-state awareness (temporal parietal junction) as well as the core of the network (precuneus and posterior cingulate cortex). The default-mode network is also often active when people are trying to figure out other people's intentions and feeling, and Lutz et al. speculate that this is what might be going on here: mentalizing, putting oneself in the place of all the beings one feels compassion toward.

The anterior insula and the anterior cingulate cortex—that is, the salience network—were also more active during compassion meditation than during rest, as was the amygdala—the emotion center of the brain. Interestingly, when emotional sounds were played, the right insular cortex was the only brain area that reacted differently in novices and experts: Only in experts did it react more strongly to negative sounds. This activity was also related with the degree to which meditators indicated they had successfully entered the meditative state: The deeper the meditation, the stronger the activation in the insula. These results suggest that the meditation set up the participants to check out emotional stimuli—perhaps a readiness to empathize with others—and experts in compassion meditation perceived negative stimuli—the sound of a suffering fellow human being appealing to their compassion—as acutely pertinent.

Compassion meditation also led to an increase in heart rate but not breathing frequency. The change in heart rate correlated with the activation in the insula, and especially so in experts. This suggests that compassion practice effectively counteracts some of the usual parasympathetic, calming effect of meditation. Teachers often prescribe heart practices when meditators feel drowsy or sleepy,[58] and this may be the reason: It is, indeed, regardless of its emotional impact, an invigorating exercise.

In the second study on heart practices, Maria Engström and Birgitta Söderfeldt[59] tested a single highly experienced meditator (who, besides her daily practice, had also participated in two three-year-long traditional Tibetan Buddhist retreats). In the scanner, she cycled three times through 30 seconds of compassion meditation, accompanied by a mantra, and two periods of repeating sentences. Like Lutz and colleagues, the researchers found activation in the anterior cingulate and the right insula, as well as in the right caudate. The caudate is implicated in, among other things, processing of emotions.

In the third study, Tatia Lee and colleagues[60] examined 12 meditators with, on average, about 7,500 hours of compassion-meditation practice. During meditation, the participants viewed a set of 20 neutral, 20 happy, and 20 sad pictures. They rated how emotional they thought each picture was. The main finding was that experts who were viewing sad pictures activated the left medial frontal gyrus and the left caudate more strongly than novices did; while they were viewing happy pictures, experts showed higher activation in the left anterior cingulate, the right medial frontal gyrus, and the right precuneus. This suggests that compassion meditation experts react more strongly to a display of sad emotions (anterior cingulate) and identify more quickly with happy sentiments (left caudate). In both cases, they were also more efficient in regulating these emotions (the middle or inferior frontal gyrus).

A different picture, however, emerges from the fourth study, by Judson Brewer and colleagues[61] (12 meditators with about 10,000 hours of practice). In this study, loving-kindness meditation specifically deactivated the amygdala and the hippocampus. The hippocampus tends to be associated with, among other things, the retrieval of memories and planning for the future. Its deactivation suggests that meditators were on focus, that is, not mind-wandering, and likely less self-centered. The amygdala is intimately linked with the processing of emotions. Its deactivation might mean that emotional stimuli in general are temporarily shut out of awareness—a conclusion opposite to that of Lutz and colleagues. It could, however, also mean that the brain's alarm system calms down as the meditator infuses himself with the emotions and sensations of loving-kindness (the amygdalae are notable for reacting very quickly to fearsome stimuli[62]).

Finally, Kathleen Garrison and colleagues[63] replicated and extended the results from the Brewer et al. study in a group of 20 expert meditators (with about 10,000 hours of accumulated practice, on average). Specifically, they found that experts showed lower connectivity between the inferior frontal gyrus and the posterior insula and the rest of the brain. The inferior frontal gyrus is often implicated in emotional processing and empathy,[64] and so Garrison et al.'s result suggests that experts engage in *less* emotional processing during loving-kindness meditation than novices do.

How to summarize these diverse results?

For one, it is clear that, unlike the two attention-based practices, loving-kindness and compassion meditation have a clear impact on emotion-related structures in the brain. There is an interesting discrepancy here, however: Three studies show a heightened sensitivity or receptivity to emotions; two show a decrease in emotional processing. I think the key difference is that the second set of studies looked at loving-kindness/compassion meditation as it occurred, undisturbed. The first set of studies, in contrast, interrupted the meditation with emotional stimuli—sounds of distress or joy, or pictures of happy or sad events. The differences in emotional processes between the two sets of studies might be telling here: In the first set of studies, the salience system was engaged, as was the system related to processing of the self, but this was not the case in the second set of studies.

What might be happening, then, perhaps, is that during uninterrupted loving-kindness meditation the self-related network and the salience system are allowed to go silent because the object of meditation is clear and predictable; that is, there is little room for mind-wandering. When emotional sounds or pictures puncture your loving-kindness meditation, however, the salience system reacts swiftly, and the connection between the perceived suffering and yourself is quickly established. Thus loving-kindness meditation appears to be both a practice that is cool and composed and a practice that primes you for compassion and loving-kindness, if the need to exercise those would arise.

Long-Term Meditation Expertise

No one is born a meditator—it takes time, effort, and dedication to develop the skill. Most (but not all) of the studies I describe in this chapter were done on highly accomplished meditators, with often tens of thousands of hours of practice under their belts (or robes, in many cases). Given that there are few studies of less accomplished meditators (people like me, and maybe you), it is hard to trace the development of meditation expertise from monkey mind to monk's mind.

Here is what we do know.

First, we know that, over time, **meditators develop the skills associated with the type of meditation they engage in.**

In her meta-analysis on attention practices, Tomasino et al. also looked at differences between long-term and shorter term meditators (the dividing line was at 5,000 hours of total accumulated practice—quite a lot). They found that long-term meditators activated the attention brain circuits to a lesser extent than shorter term practitioners did, suggesting that as the meditation practice matures, less effort is needed to sustain a sitting.

Tomasino et al.'s contrast was between studies; that is, they contrasted studies in which the average level of expertise was high with those where it was lower. A potential problem here is that studies differ in many aspects—maybe the studies with long-term practitioners used simpler meditations and thus placed lower demands on the yogi's attentional systems.

When we look at studies that include individuals of different levels of expertise, we find a more mixed pattern. Antonietta Manna and colleagues[65] found the same result as Tomasino et al. when comparing monks with about 16,000 hours of practice with novices—monks showed decreased activation in attention structures. Baron Short and colleagues[66] found the opposite result when looking at lay meditators (splitting the sample in meditators who had an accumulated record of less than or more than about 2,000 hours)—increased expertise leads to increased activation in attention structures. Julie Brefczynski-Lewis and colleagues[67] found the solution to the riddle: They obtained *both* results when they split their group of meditators into three—experts (19,000 hours of accumulated practice) showed stronger activation than novices, but experts with 44,000 hours of accumulated practice showed less activation than novices. What seems to be happening, then, is that meditators initially learn to build up attentional effort (and this takes many years); when they have done so, they slowly become more efficient. Part of the growing efficiency is that expertise builds stronger connections within the attention network, as we will see in a bit more detail in the next chapter. Likewise, experts show stronger couplings between the attention network and the default-mode network, which makes it easier to suppress mind-wandering, as Hasenkamp and Barsalou found.[68]

Part of this fine-tuning of attention might be developing a better sense of the sometimes subtle signals that tell you that the meditation is going where it is supposed to go. Earlier I discussed the findings from Kathleen Garrison et al.'s study where research participants were shown a real-time graph of their PCC activity and were asked to meditate themselves into either the red or the blue zone of PCC activation or deactivation. An important additional finding from this study was that only long-term meditators were able to do this; novices were not. Expert meditators may thus be more sensitive to nuances in their inner states, connect those with the graphs, and use this knowledge to guide them toward deeper or shallower states of concentration, as the task required. This result also casts doubt on some of the claims made by commercial enterprises (I won't name any here) that meditation can be taught through biofeedback. The reason for the doubt is twofold: One is that collecting reliable default-mode network signals is hard to do outside the scanner[69]; the other is that you might need a lot of experience with meditation before you can use such signals to your advantage. We do know that biofeedback can teach you to relax,[70] but meditation is much more than chilling out.

A second finding is that, over time, there seems to be a **trend toward disembodiment and selflessness**. Tomasino et al.'s meta-analysis found that long-term meditators show more activation in the supplemental motor areas and in the superior medial gyrus than less experienced meditators—evidence for a growing disembodiment with longer practice. Previously I cited the results from the study on selflessness by Dor-Ziderman and colleagues, which suggests that true selflessness, as characterized by a lack of ownership over experiences, can be reached only after an extremely large amount of practice. Both of these outcomes of meditation are side effects—they are not the actual goal of practice (at least not in these traditions). This perhaps implies that they are a natural outflow of the amount of time spent in meditation. Tomasino et al. describe this as a strategy shift: Seasoned meditators might focus less on controlling their attention and instead concentrate more on disembodiment. This might fit with the (non-)strategy of "no-efforting" that Garrison et al. found in their expert meditators.

Third, there is also some evidence that more experienced meditators take **less of a judgmental, evaluative, or emotional stance in meditation**. Two studies support this idea. First, Manna et al. found that novices simultaneously activate the anterior cingulate (part of the salience network) and the lateral orbitofrontal cortex during open monitoring. The lateral orbitofrontal cortex is involved in affective and cognitive evaluations, and so it appears that either whatever you are monitoring is being evaluated, or you check in on your evaluations, or both. This coupling was absent in expert meditators, suggesting that experts let go of their evaluative mindset. Second, Brefczynski-Lewis et al. presented emotional sounds toward the end of short meditation periods. They found a strong negative relation between accumulated number of hours of practice and activation in the amygdala (a region associated with gut emotionality) and the posterior cingulate cortex (part of the default-mode network), suggesting less emotional reactivity and less distraction in highly accomplished meditators.

Fourth, **over time, meditators become more meditative in daily life**—or at least they might use idle moments as meditative opportunities. This isn't really something researchers were looking for, so it's a bonus finding. They happened to stumble across this result when comparing the brains of meditators with those of nonmeditators when both were lying idle inside the scanner or the testing room and asked to do nothing in particular. This is illustrated in three examples.

First, in an EEG study, Rael Cahn et al.[71] found that long-term *Vipassanā* meditators (with, on average, 19 years of practice) showed just as much alpha power in their brainwaves during rest as during meditation, and this level was higher than that of meditators with fewer years of practice (2.5 years, on average). As we have seen, meditators likely generate these alpha waves during meditation as they turn off distracting thoughts. The new finding is that experts also generate those waves when they are just sitting around, not doing anything in particular. Cahn et al. interpret this as a trait difference: The meditative habit starts seeping into every aspect of daily life; it becomes part of your personality. Another interpretation is that meditators simply slip into meditative states whenever there isn't anything in particular that needs their attention—like when they are waiting for the researchers to start up their experiment.

Second, in their fMRI study, Judson Brewer and colleagues found a strong coupling between the default-mode network and the salience network in long-term meditators, regardless of what type of meditation they were engaged in. But this didn't happen only during meditation: The same coupling was found during a rest period. As I mentioned, Hasenkamp and Barsalou obtained a similar result: Longer meditation practice was associated with a stronger coupling between the default-mode network and the attentional network at rest. These two studies suggest that the meditative state carries over, with meditators bringing more attention to their inner states, at least when resting inside the scanner.

Third, Antonietta Manna and colleagues found that the brain patterns of Buddhist monks during rest resembled those of open-monitoring meditation but not focused-attention meditation; novices' brains did not look meditative at all. The conclusion here would be that monks practice open monitoring also in nonmeditative conditions or, again, at least when waiting inside the scanner.

The three key findings concerning the long-term development of meditation—meditation becomes less effortful over time, during meditation meditators become more self-less as well as less judgmental, and the meditative state increasingly spills over into nonmeditative moments—suggest that long-term meditation (or maybe even short-term meditation) might leave lasting imprints on the brain and likely leaves traces on behavior off the cushion as well. We explore those possibilities in the remainder of this book.

A final note on this: None of the studies cited here suggest that there are cutoffs or stages in meditation practice. Rather, when researchers plot activation (or some other measure of how meditation is implemented in the brain) as a function of accumulated practice, the plots all look wonderfully continuous even if—in the attention case—curved. There are, as far as we know, no steps, no plateaus, no sudden jumps. Thus meditation expertise (like just about any other form of expertise) is built gradually, and also—another fascinating point to consider—it never ends. The Buddha himself, after his peak experience at age 35, kept practicing for another 45 years—tradition has it that he died while meditating, at age 80.

There is one exception to this pattern, as we have seen, and that is the experience of selflessness,[72] which, in its form of loss of ownership, is something that does look like a qualitative jump and one that can only be made after a tremendous amount of practice. This may be one reason why this experience, in some Buddhist traditions, is considered the hallmark of awakening.

{ 4 }

Telltale Traces in the Brain

One of the brain's more incredible properties is its plasticity: The brain constantly rewires itself in an endless run of updates. In a very real sense, you can never use the same brain twice.

Some of these changes are self-evident. For instance, many experiences, especially rare or emotional or highly important ones, leave more or less permanent imprints on the brain—that's what memories are.

Some types of plasticity may be less obvious. For instance, repeatedly performing a particular action leaves its mark on the brain structure that is needed to perform this action: It starts to grow.

One of the first studies to show this type of plasticity in humans, by Eleanor Maguire and colleagues, was done on London taxicab drivers.[1] London is a very complicated city to navigate (not like most North American cities, which are built on a rectangular grid, often with streets that have numbers for names). In order to be licensed, cab drivers have to prove they know the shortest route between any two points in the city—they have to pass a mysterious-sounding test called The Knowledge. Both the intense study of maps necessary to pass The Knowledge as well as the actual driving around in the city would build navigation skills. Maguire et al. found that the part of the brain that is associated with spatial navigation, the back part of the hippocampus, was larger in cab drivers than in other Londoners. They also found that this growth came at a price—cab drivers had a smaller front part of the hippocampus (the part that handles memory).

Sometimes such changes occur very rapidly. In one famous study,[2] 12 undergraduate students learned to juggle; they were compared with other students who did not practice this skill. After only three months, two parts of the jugglers' brains had grown larger, namely V5, which specializes in motion perception, and the left posterior intraparietal sulcus, which plans and executes movements that involve objects. After another three months in which the jugglers were asked to not practice their newly acquired skill, these two areas shrunk about halfway back to their original volume. Thus plasticity can (at least under some circumstances, maybe with a relatively simple, well-defined skill) turn on and off quite rapidly.

In this chapter, I look at differences in the structure (or "morphology") of the brains of meditators compared with the brains of nonmeditators and at changes in structure within meditators over the course of their practice. Chapters 2 and 3 were all about the brain activity associated with meditation; this chapter investigates what lasting changes are wrought by this activity.

What Brain Changes Should We Look For?

Note that it is unlikely that we will find any qualitative differences between the brains of meditators and nonmeditators. That is, there is no reason to suspect that the brains of meditators would have different parts, or would be wired differently, or would be arranged in different ways. More likely, we will find quantitative differences, that is, differences between meditators and nonmeditators in shape, mass, or volume of particular brain regions, as we can see them on MRI scans.

In practice, three types of measures have been used to examine such differences. The first is simply *volume*: how large a particular brain region or structure is. The second is called *gray matter density* or *gray matter concentration*, and it is a bit less intuitive. Scanners do not take a 3D picture of the whole brain. Rather, they build a 3D representation of the brain by taking multiple 2D pictures of a slice of brain tissue (rather like making a cut and examining both sides of the cut); then they stack these images. These slices have a thickness to them (often a millimeter or so). Within each slice, the picture actually consists of a set of small blocks, called voxels. You can think of voxels like pixels on a computer screen, only in 3D, hence the name, short for "volume pixel." Voxel size differs with the strength of the scanner and the way scanning is done but is typically around 2 mm^3—enough to contain over a million neurons. Density is defined as the amount of gray matter inside a voxel; the gray matter density of a particular brain structure is the amount of gray matter combined over all voxels that fall within that structure.

For both of these measures, volume and density, the actual reason behind any changes we might find is ambiguous: Gray matter is made up of the cell bodies of neurons, the end nodes of neurons, glial cells (cells that provide support and protection for neurons), and capillaries (small blood vessels). Thus if we find that meditation increases gray matter volume or density, this could mean a number of things: New neurons have formed, existing neurons have built more connections, new glial cells have popped up, or new capillaries have appeared (the technical term for the latter is angiogenesis), or any combination of these four.

Note that although volume and density are different measures, at least two studies[3] have found that they tend to go hand in hand; that is, if you find a difference in one, you are also likely to find a difference in the other, so we could combine studies that looked at only one of the two in the same meta-analysis—exactly what was done in the one meta-analysis on brain structure and meditation.[4]

The third measure, *tractography*, is quite different from the other two. Tractography is a technique for mapping the white matter fibers that interconnect different parts of the brain; it also allows for an estimate of how strong or efficient those connections are. White matter is the stuff that connects neurons; white matter fibers, often called white matter tracts, thus send information from one part of the brain to another.

How to Study the Influence of Meditation on Brain Structure

If we find differences between meditators and nonmeditators for one or more of these measures in one or more brain regions, the hope, of course, is that these differences are telltale traces left by meditation practice. This is not a given, however. The issue is that most (but not all) of the relevant studies are **cross-sectional studies**, that is, studies in which the two different groups—meditators and nonmeditators—are scanned exactly once. This offers only weak evidence for the hypothesis that meditation is the cause of the difference. It could also be the case that people with a particular brain structure are attracted to meditation, or more successful at it, or find it more enjoyable and are thus more likely to stick with it.

Consider, for instance, the finding that meditators have larger attention centers in the brain (an outcome that has actually been observed, as we will see). I hope I have convinced you by now that meditation is a form of attention training, and so it is tempting to conclude that this training translates into an increase in relevant brain tissue. But it might also be possible that it is the other way around: People who are better at paying attention (and so might have larger attention centers in their brain to begin with) might take to meditation more organically than people who are naturally more scatter-brained.

So how can we establish that differences between meditators and nonmeditators are due to the meditation history of the meditators and not to preexisting differences between meditators and nonmeditators or to chance?

The previous argument, namely that what we see makes logical sense—meditation trains attention, and so if we see differences in attention skills between those who meditate and those who do not, this must be due to attention—is a weak argument. The **convergence argument** sometimes used in research papers—that is, that some regions found to show structural changes in the brain are also found to be activated during meditation—is not much stronger: The causal link could still be reversed: Brain regions might activate more strongly because they contain more neurons, more connections, or more capillaries, and so these preexisting differences between meditators and nonmeditators might show up in brain activation as well.

The only type of study that can unambiguously establish the direction of the effect (i.e., brain → meditation, or meditation → brain) is a **longitudinal study**. In longitudinal research, two groups—nonmeditators (the "control" group) and beginning meditators (the "treatment" or "intervention" group)—are followed over a period of time so that we can actually look at *change*. Crucially, in these studies, everyone's brain is scanned at at least two time points, once before the treatment group starts meditating and once after this group acquires some skill in meditation. Two types of comparisons can be made. First, we can compare "after" with "before" in both groups and see if meditators make more progress than nonmeditators. Second, we can compare meditators with nonmeditators after the intervention to see if differences between meditators and nonmeditators emerge after treatment. (At first blush, it may seem strange to have the second comparison when we have the first. One reason to look at differences after treatment is that this is the statistic that matters to policymakers: How well are people who went through a particular treatment doing compared to their peers who did not undergo treatment? A second reason to look at differences after treatment is that cross-sectional studies by definition only provide this second comparison, and so by using this "after" contrast, we can directly link longitudinal and cross-sectional studies.) In an ideal study, we would also scan at multiple time points along the way, and have a follow-up test as well, so that we can have a good look at the development of expertise and check if expertise is sustained.

Longitudinal studies into true meditation expertise are not very feasible, alas—as we have seen, the people whom researchers in this field consider to be meditation experts have spent many thousands of hours of practice on the cushion. There are, however, a few intrepid researchers that have been brave enough to investigate the effects of short-term interventions, notably eight-week MBSR programs, on brain structure with a longitudinal design.

To some extent, the longitudinal design can be simulated by having differences stand in for change. You can do this by comparing meditators of varying degrees of expertise and relating the level of expertise to one or more measures of brain morphology. Suppose we find, for instance, that in meditators with one year of expertise, brain region *X* has a volume of 10 mm^3 and that this structure has a volume of 12 mm^3 in meditators with three years of expertise and 14 mm^3 in those with five years of expertise. In this example, each year of expertise translates into a 1 mm^3 increase in brain volume in region *X*. Researchers in pharmacology call this a **dose–response relationship**. The dose is the amount of meditation expertise; the response is brain volume in region *X*. It is still technically possible that a dose–response relationship is due to chance or to preexisting differences between these three groups, but it is also quite unlikely.

I should note here that dose–response relationships have been found in plasticity studies outside the field of meditation research. In the London cab driver study, for instance, the increase in volume in the back of the hippocampus was directly related to the number of years on the job; in the juggling study, the students who were better at juggling (presumably because they practiced more) also had larger increases in volume in the two critical regions.

How Meditation Changes the Brain: What the Sample of Participants Looks Like

As in my review of the literature on brain activation, I take a recent meta-analysis of the literature as my starting point. There is only one at the time of writing, by Kieran Fox and colleagues.[5]

As with the Tomasino et al. meta-analysis on brain activation, it may be a good idea to first have a good look at what type of meditators we are talking about here. Fox et al. collected the results from 21 studies. The total tally across all studies is 503 meditators and 472 nonmeditators. Because some participants were tested in more than one study, the number of actual people tested is smaller still, namely about 370[6] meditators. All but one of the 21 studies looked at cross-sectional differences between meditators and nonmeditators; five also included a longitudinal component. The longitudinal sample is extremely small, however: Only 114 people were tested before and after participating in a meditation program; they were compared to 90 control participants.

There are four noticeable differences between this set of studies and those on brain activation during meditation. One is that the amount of meditation expertise is lower here (4,664 lifetime hours of lifetime expertise, on average, versus 11,552 lifetime hours for the Tomasino et al. analysis; that is still a lot of experience). A second difference is that the morphology studies, as far as I can tell, all use laypeople—no monastics have been tested. The third is that fewer studies (12 out of 21) focused on participants who practiced meditation within an explicit Buddhist tradition. The fourth is that five of these studies (i.e., about one-quarter) recruited their participants from an MBSR or MBSR-like program,[7] that is, a relatively short and decidedly nonreligious training program.

Again, this is a sample that is, on average, highly proficient and well trained in meditation, and likely not very representative of the average Western meditator. That said, the sample is also less extreme in their accomplishments than the sample in the activation studies I discussed in Chapters 2 and 3. This is probably because it is easier to recruit participants at your nearest Zen or *Vipassanā* center than to find a Buddhist monastery, and it is less critical for these kind of studies to have truly unflappable meditators. In morphology studies, what your mind actually does inside the scanner is unimportant as long as you keep your head still, so you could simply rest, or daydream, or make your shopping list.

Before We Start: Publication Bias

There is one important caveat with this set of studies, and that is the possibility of publication bias. What is publication bias?

Here is the scientific publication process in a nutshell: You conduct your study, you analyze your results, you write them up, and you send it off to a journal. The editor of the journal (a fellow scientist) will send your manuscript to two or three other scientists to check on its merits and demerits. These two or three colleagues write a detailed, anonymous review. These reviews almost always contain suggestions for changes—new citations to be added, new analyses to be performed, questions for clarification, errors in reasoning or in the design of the study, and so on. On the basis of those reviews, the editor makes a decision about whether to publish it. When the paper looks good, the decision usually takes the form of a "revise and resubmit"; that is, you are invited to rewrite your manuscript to incorporate some or all of the changes suggested by the reviewers or to counter the reviewer's points of criticism.

The publication process has many rejection moments built in, starting with the researcher: When you analyze your results, do you like them? Assume, for instance, that you conduct a study on brain morphology and meditation and you do not find any differences, or you find something unexpected that runs counter your ideas (e.g., you find that the attention centers of meditators' brains are actually smaller). In that case, you might be tempted to shelve the results right away, because you think they do not make sense, or because you think they will never make it past the reviewers.[8] If you do write up the results, the reviewers might lambast you for trying to publish "null results" (another technical term—results that say there is nothing there) or for showing results that you, or they, cannot explain, and so the editor rejects the paper and it never sees the light of day.[9] This creates a publication bias in that studies reporting a positive result are more likely to be published and studies that found a null or negative result are less likely to be published.

How can we know that publication bias exists in a particular set of studies? The best way is to ask around and see if there's anyone who has unpublished studies lying around—but who do you ask, and will they be truthful in their answer? One slightly sneakier way to get at publication bias is to probe for indirect evidence that a specific type of result is missing. This involves capitalizing on the law of large numbers: If you have a study with many participants, it is more likely to reveal the truth than a study with only a small group of participants. I gave the example of political polling earlier—asking a few thousand folks whom they will vote for is a better way to predict the outcome of an election than asking just 20 people.

So one way to look for publication bias is to see what the effect size is in the largest studies, and then see if smaller studies show effect sizes that are symmetrical around this large-sample effect. That is, we would expect that smaller scale studies show more randomness, but if random is really random, this should work in both directions: Half of the studies should show a larger effect and half a smaller effect. Also, the studies with the smallest number of people should be off by a larger amount. That is not what Fox et al. found in the brain morphology studies: In effect, *all* smaller scale studies showed effects that were larger than the effect in the large-scale studies, and *all* studies showed a positive effect. This is highly suspicious, and it makes it very likely that publication bias is operating—studies with null effects simply don't make it into print.

This doesn't mean that the results cannot be trusted. First, publication bias in and of itself is unlikely to lead to convergent results between studies, which is what the Fox et al. meta-analysis ultimately set out to determine. If the effects that have been published were all random, there should be very little consistency in the actual brain regions that are being found to differentiate between meditators and nonmeditators. If we find that there is consistency, the result of publication bias is that we will overestimate the size of the effect, but its location should still most likely be correct. Second, the effects in large-scale studies are not zero—the large-sample effect size is still about 0.5 *SD*.

In sum, what the presence of publication bias does mean is that the "true" size of the effect (i.e., its size if we were able to get those unpublished studies out of the file drawer) is likely much smaller than what Fox et al. reported in their meta-analysis.

Excitement Versus Replication: Averaging across Studies

As I mentioned in Chapter 1, and again when discussing the Tomasino et al. map, the aim of meta-analysis is to find convergence among studies. It does so by averaging results across studies. Recall that one consequence of this is that differences in brain structure between meditators and nonmeditators that are only found in a few studies are not likely to figure heavily in the final verdict. One example of this is an excellent study[10] that looked at brainstem volume and found that areas in the brainstem that regulate breathing are enlarged in meditators. This result is exciting because it makes sense—after all, meditators are keenly attuned to their breathing—and it also has important implications—for instance, it might explain the effects of long-term meditation on stress reactivity. (And you might read such claims in the media reports on this study.) Much as I like this result, it has not been replicated—no other study has found it—and so it remains a lonely data point that did not become significant in the Fox et al. meta-analysis. This is the way it should be—after all, one of science's mottos is (or should be) "replication or it didn't happen."

Given the modest number of studies, the meta-analysis also by necessity averages across aspects that we probably shouldn't average across, such as the particular tradition the meditators practice in, different levels of expertise, the ultimate goal of the training (stress reduction vs. enlightenment), and the like. How much this truly matters is unknown. For instance, we might expect that traditions that emphasize focused attention might lead to different brain changes (maybe more thickening in executive control regions) than traditions that put open monitoring to the fore (which might yield larger modifications in the salience network). An early review found exactly these differences between *Vipassanā* and Zen,[11] but—perhaps unsurprisingly, given the mixed results in activation studies, as shown in Chapter 3—later studies have not borne this out.

The Fox et al. Meta-Analysis: Changes in Gray Matter

Looking at changes in **gray matter** first, Fox et al. found eight brain regions with more or less consistent increases in volume and/or density: (a) the anterior and mid insula, (b) the sensory and motor cortex (including the supramarginal gyrus), (c) the anterior precuneus, (d) the rostrolateral prefrontal cortex, (e) the anterior cingulate cortex and the medial cingulate cortex, (f) the orbitofrontal cortex, (g) the inferior temporal gyrus and the fusiform gyrus, and (h) the hippocampus. They also found two regions that show more or less consistent decreases in volume and/or density: (a) the posterior cingulate cortex and (b) the precuneus.

One way of looking at these findings is to check for convergence with the Tomasino et al. map. The assumption would be that brain areas that are activated during meditation would also show structural changes. Under this view, meditation is a skill that is continuously being honed, and this honing leaves its marks on the brain.[12] You may have noticed that a few of Fox et al.'s regions sound familiar from Tomasino et al.'s map or from the discussion in Chapter 3 (anterior insula, anterior cingulate cortex, supramarginal gyrus, posterior cingulate cortex, and precuneus). You may also have noticed absences—regions that are on Tomasino et al.'s map but not on Fox et al.'s (e.g., superior parietal lobe, medial prefrontal cortex)—and regions that are on Fox et al.'s map but not Tomasino et al.'s (e.g., the sensory and motor cortices and the hippocampus).

It seems to me that what is important here is not the region-to-region correspondence between the two maps but the parts of the wider story that overlap. Recall that we viewed Tomasino et al.'s map as a map of four fields of activity: (a) control over attention, which results in a silencing of the default-mode network; (b) an increased focus on body sensations; (c) a decreased sense of global body awareness; and (d) a quieting down of the storytelling mind. Some of these themes are also present in Fox et al.'s map, suggesting, indeed, that repeated activation of these brain regions in meditation might result in structural changes. (Although, as noted earlier, it might also be the other way around—structural differences leading to different levels of activation.)

With regard to **attention**, Fox et al. find morphological changes in the *salience network*—most notably an increase in the anterior cingulate cortex and the anterior insula. We've encountered plenty of studies in the previous chapter that show that meditation tends to activate these structures.

The evidence for changes in *executive control* is maybe harder to detect—the major players in the frontoparietal control network do not figure in Fox et al.'s map. Fox et al. did, however, find increased volume and/or density in the rostrolateral prefrontal cortex (sometimes labeled the anterior prefrontal cortex). This area is not on Tomasino et al.'s map, but it is an area that was activated in Hasenkamp et al.'s study on mind-wandering during meditation, notably during the phase of becoming aware of being distracted and during the phase of shifting attention. One influential theory[13] about this region is that it selects the set of tasks that the mind needs to perform. More specifically, the rostrolateral prefrontal cortex acts as a kind of gateway that enables switching between attending to environmental stimuli (in meditation: the breath, sensations in the body, or sounds) and internal stimuli (in meditation: thoughts, mind-wanderings, memories, and the like). This, then, would be considered flexible executive control. You could even argue that this is the type of control that the meditating mind is practicing all the time. (Or at least the part of the time when it isn't dreaming away.)

From Fox et al.'s map, it seems like these types of control might be successful, that is, major parts of the *default-mode network* (the posterior parietal cortex and the precuneus) are lower in volume and/or density in meditators than nonmeditators. Tomasino et al.'s map showed that both of these areas deactivate during meditation.

Quite a number of the increases in volume and/or density on Fox et al.'s map point at more efficient **direct awareness of specific body sensations**: the insula (also part of the salience network), the anterior precuneus, and the sensory and motor cortex. The increase in volume and/or density in the supramarginal gyrus (parallel to activation in this structure on Tomasino et al.'s map) points to changes in **global body awareness.**

Finally, some of Fox et al.'s results are in line with Tomasino et al.'s findings concerning the **quieting down of the narrative self**. Notable here is the decrease in volume and/or density in the precuneus—echoing its deactivation on Tomasino et al.'s map. The precuneus is an area within the default-mode network structure that is keenly associated with the self-as-story.

Thus the tale I spun from Tomasino et al.'s map is largely repeated here, suggesting that changes in brain functioning during meditation (as measured by activations and deactivations) go hand in hand with changes in gray matter structure. Again, this is a suggestion, a story, not a hard fact.

Interestingly, the Fox et al. map also has three regions that do not show up in the Tomasino et al. analysis. The first of these is the **right orbitofrontal cortex**.[14] This region is associated with a number of functions, including decision-making; that is, it quickly assesses and integrates information to predict what a specific situation could mean to you and what the outcome of a specific decision might be.[15] Others have pointed out that the orbitofrontal cortex (like the anterior insula, also on Fox et al.'s map) is also richly connected to the limbic system, that is, the emotional part of the brain, and serves to down-regulate emotion and reappraise negative situations in a more positive light.[16]

Both of these functions might fit with results of meditation practice as meditators often experience them. Meditation might help, for instance, with shifting the off-the-cushion meditator away from more reflexive, customary reactions to the world around them toward the more dynamic, predictive—shall we say mindful?—kind of decisions that the orbitofrontal cortex performs.[17] And it may be the case that the repeated practice of letting go, practiced over and over through the orbitofrontal cortex, may in turn lead to positive effects on negative emotional states, such as depression and anxiety, as we shall see in Chapter 6.

The second result that is unique to Fox et al.'s map is the increase in volume and/or density of the **fusiform gyrus and inferior temporal gyrus**. It should be noted that some fMRI studies have found activations in this region as well, so this may be a case of convergence between activation and morphology after all.[18] Fox et al. point out that these findings "appear puzzling and have been little discussed." The reason is that these areas are usually associated with visual processing, and given that meditation is typically done with the eyes either closed or half-open, this makes little sense. Fox et al. suggest, with James Austin,[19] that this area may be associated with the visual hallucinations or imagery that sometimes pop up, especially during long sitting periods or during retreats. (For more on these hallucinations, see Chapter 3.)

Finally, Fox et al. finds consistent evidence for an enlarged **hippocampus** in meditators. He offers three explanations.[20] First, the hippocampus is part of the default-mode network, and so this difference might signal the higher levels of attention that meditators (especially of the open-monitoring variety) offer to spontaneous thoughts as they arise during meditation. (This, of course, stands in contrast to the shrinkage in the precuneus.) Second, the hippocampus is also a memory structure, specializing in the transfer of short-term memories into more permanent storage. Fox et al. speculate that it is possible that meditators spend a lot of time—not necessarily on the cushion—reviewing, reexamining, and reintegrating memories, placing past experiences in a new light, all in the interest of finding new freedom in their actions and reactions. Third, the hippocampus, with its many connections to the limbic system, also plays a role in emotion regulation and stress resilience. For instance, it is smaller in people with posttraumatic stress disorder. In rats, growing up in an exciting environment (by which we mean not in a bare cage) increases the size of the hippocampus, and this in turn works to buffer against stress.[21]

One possible solution to the puzzle comes from a study by Eileen Luders and colleagues,[22] which looked in more detail at exactly which part or parts of the hippocampus were enlarged in meditators. They found significant effects only for the subiculum, the lower part of the hippocampus. The role of the subiculum is still not completely mapped out, but we do know that one of its functions is to regulate stress via what is called the hypothalamic–pituitary–adrenal axis, or HPA axis.[23] Remember the discussion earlier about the parasympathetic and sympathetic nervous system? The HPA axis is what sets the parasympathetic system in motion. Basically, when something stresses you out, the following sequence of events unfolds: The hypothalamus (part of the limbic system in the brain) starts releasing corticotropin-releasing hormone, which causes the pituitary gland to release adrenocorticotropic hormone (also known as corticotropin), which then signals the adrenal cortex to start producing glucocorticoid hormones (mainly cortisol), epinephrine (also known as adrenaline) and norepinephrine, and off you go on your fight-or-flight response. The subiculum is intricately connected to this system, acting as a brake—it stops or limits the response of the HPA system, more specifically the release of cortisol that sets the actual stress response in motion. Thus, even when a stressor comes along, the subiculum can still intervene and prevent your heart rate from going up, your lungs from gasping for air, your blood pressure from skyrocketing, your sweat glands from pumping, and your digestion from coming to a grinding halt. (Ever known a meditator who is preternaturally calm, even when poked? That's possibly a more than fully grown subiculum in action.)

Interestingly, this may be a circular process. Stress hormones (particularly cortisol) slowly destroy hippocampal tissue.[24] If meditation, or the habit of meditating, brings about a reduction of the **stress response** (through repeated return to the breath, an increased parasympathetic response, or the increasing habit of being able to let go of the small stuff), then this might have the added effect of preserving the hippocampus from the normal wear and tear of daily life.

The average effect size over all these structures in all these studies is quite large—about .75 of a standard deviation (0.77 *SD*, to be precise). As I mentioned, this is likely an overestimation. Fox et al. applied some fancy statistics to obtain a better estimate and concluded that the true effect is more likely about 0.44 *SD*. This means that 67% of people in the control group have lower volume/density in these structures than the average meditator (or larger, for the precuneus and the posterior cingulate cortex).

Another (maybe more surprising) way to look at these brain changes is to consider that meditation might counteract aging. In many of the studies that are represented in the Fox et al. map, there is a wide age range in the meditators and controls. Two studies[25] have calculated correlations between volume of particular regions and age. One found a correlation between total gray matter and age of $r = -.54$ for controls but a zero correlation in meditators ($r = .01$); one looked at the right frontal region and found a negative correlation in controls ($r = -.76$) and an essentially zero correlation in meditators ($r = -.05$). These are only two studies, but the suggestion is that meditators' brains (or parts thereof) show less age-related decline (i.e., in these two cases, no aging at all) compared to the brains of those who do not meditate (which show quite a bit of shrinkage with age).

The Fox et al. Meta-Analysis: Changes in White Matter

What happens in white matter, the bundles of nerve fibers that connect different parts of the brain?

Fox et al. found two pathways that show higher efficiency in meditators. The first is the **corpus callosum**. You may know that the brain comes in two halves ("hemispheres"). The corpus callosum connects those two halves. Meditators have an enlarged corpus callosum, especially in the front of the brain (the genu and the forceps minor), suggesting that information transfer between the two brain halves proceeds more efficiently. This may be a byproduct of all the activation going on in different areas of the front of the brain during meditation (such as the insula, the anterior cingulate cortex, the rostrolateral prefrontal cortex, and the orbitofrontal cortex).

The second is the **superior longitudinal fasciculus**. This is one of the brain's main front-to-back-to-front pathways; it connects parietal regions (like those associated with body awareness) with frontal regions (like those involved in attention). The different subcomponents of this tract are responsible for things like the sense of your body in space, the moment-to-moment understanding of the state of your body, spatial attention, and control over your focus of attention.[26] The most likely story here is that this enhanced connection represents the fruit of repeatedly and persistently paying close attention to fleeting sensations in the body (i.e., the breath and/or bodily sensations).

Eileen Luders and colleagues[27] have looked at how well these white matter tracts[28] still work with advancing age. Over 20 different tracts, the correlation with age was $r = -.69$ for nonmeditators, compared with –.25 for meditators. This is only a single study, but the message is again that meditators' brains may be less susceptible to the negative effects of aging than those of nonmeditators.

Dose–Response Relationships

All the previous findings fall within the "weak" category of evidence for the existence of a causal connection—the results could also be due to preexisting differences between meditators and nonmeditators rather than to the practice itself.

Fortunately, a number of studies have recruited meditators that differ widely in meditation experience. This allows the researchers to correlate experience (typically the number of years the meditators have been meditating) with volume and/or density of particular brain regions.[29] As already explained, the existence of a dose–response relationship (more meditation experience is associated with an increase or decrease in volume and/or density) would be stronger evidence for the position that meditation practice *changes* the brain.[30]

With regard to the **salience network**, two studies Grant et al. (2010) and Hö̈lzel et al. (2008) report a correlation between meditation experience and volume/density in the anterior cingulate cortex; the average correlation is .21. The average correlation between experience and volume/density in the insula (if we consider the insula as part of the salience network) is .38,[34] Hölzel et al. (2008), Luders et al. (2009), and Luders et al. (2012b).

With regard to **executive control and the default network**, the single study[34] that analyzed the correlation with the rostrolateral prefrontal cortex failed to find one; one study Grant et al. (2013) found a high positive correlation between experience and volume in the precuneus (.50); nothing is known about the posterior cingulate cortex.

With regard to **direct awareness of bodily sensations**, the correlation between meditation experience and volume/density in the insula (if we consider the insula as part of the body-sensation regions) is about .38; the average correlation between meditation experience and volume/density in the somatosensory cortices (one study)[34] is .71; the two studies Grant et al. (2013) and Kang et al. (2013) that looked at the supramarginal gyrus found no effects. Nothing is known about the anterior precuneus.

No data are available about **global body awareness** and the **narrative self**.

With regard to regions unique to the Fox et al. map, dose–response correlations involving the orbitofrontal cortex average to .04,[34] Kang et al. (2013), inferior temporal lobe correlations to .41 Hölzel et al. (2008), Luders et al. (2009) and Luders et al. (2012b), and hippocampus correlations to .14,[34] Leung et al. (2013), Luders et al. (2009) and Luders et al. (2013).

Summarized, it seems that there are some positive correlations between experience and volume/density in gray matter, suggesting that meditation practice indeed drives the changes in brain morphology. This link is found for the salience attention network, for direct awareness of bodily sensations, for the inferior temporal lobe and for the hippocampus, but not for the orbitofrontal cortex. The verdict is still out for the executive control attention network, global body awareness, and the narrative self, simply because there are no or very few data. (It is often a cliché to state that more data are needed—here we really need them.)

Overall, these results are grounds for cautious optimism. Note, on the one hand, that the correlations are modest: Meditation experience is clearly not the only factor at play in shaping the brain. On the other hand, experience tends to correlate with age (as you gain experience, you also get older), and—as we have seen—gray matter volume and density decline with age, so finding even modest positive correlations in the face of brain aging is a wonderful result.

Brain Changes after Mindfulness Interventions

The strongest evidence for the point of view that meditation *causes* brain changes would come from longitudinal studies, in which a group of nonmeditators (the "treatment group or "intervention group") receive meditation instruction and another group of nonmeditators (the "control group") does not, and both groups are followed over time.

To date, four such longitudinal studies have been conducted. Two of these[31] have looked at MBSR programs, which involve on average around 30 hours of meditation; all measures were related to gray matter. The other two[32] have used an even shorter program, devised by their author, called "integrative body-mind training" (IBMT), with a total of 11 hours of meditation. IBMT involves body relaxation, mental imagery, and mindfulness training with musical background as help. Thus the level of expertise developed through these interventions is only a fraction of the level reached by the meditators in the Fox et al. meta-analysis (which was more than 4,500 hours on average). The total number of participants involved is small—98 meditators and 90 nonmeditators, or on average less than 25 per group in each study.

The picture emerging from these studies is mixed.

With regard to **gray matter**, one study finds no effects; one finds effects in the dorsal anterior insula and the dorsomedial prefrontal cortex; the other finds effects in the left hippocampus, the posterior cingulate cortex (with an increase in density, contrary to the results of the Fox et al. meta-analysis, which found lower density in experienced meditators), the left temporoparietal junction, and two structures in the cerebellum. Thus there is no convergence among these studies, but most of the structures that show growth over the course of the intervention also showed up in the Fox et al. meta-analysis, suggesting that, under certain circumstances, even very short-term meditation experience might lead to growth in brain regions exercised by meditation. This also adds modest (maybe very modest) confidence to the assumption that it is meditation experience that leads to brain changes. But, clearly, the main message is that we need a lot more studies on this topic, and we would probably need to follow meditators over a longer period of time.

With regard to **white matter**, there is more convergence (but then both studies were conducted in the same lab, using the same meditation program)—both studies observed an increase in white matter in the corpus callosum and the superior longitudinal fasciculus, as Fox et al. also found in their meta-analysis. The two studies also found consistent changes in the corona radiata, a white matter tract associated with attention and control over attention.[33] One of these studies also tested for gray matter changes and found none. What intrigues me in this finding—if we combine it with gray matter changes in programs that are a little longer—is the possibility that the change in white matter precedes the change in gray matter. This would also suggest that the changes in white matter might be more crucial than those in gray matter—maybe the impact of meditation on the brain lies more in the honing of pathways, that is, in increasingly efficient information transfer, than in changes in local processing of information. Given what pathways are being honed, it seems that this effect might be primarily about transferring information into the field of attention. Again, two studies is a very small number, and we need more research.

The finding of almost immediate growth in some of these studies underscores how quickly the brain is able to reorganize itself. There is another implication here—a flipside—that may be more unwelcome to you, and that is that this opens up the possibility that unlearning is equally possible. The brain changes in response to meditation experiences are just that—a response, a reaction, a way to help out with the task. If the task is no longer being performed, there is no reason to maintain the brain change. (Brain tissue is expensive; it hogs a lot of resources. Recall the juggling study: The brain regions that grew with training tended to shrink back again [at least halfway] once the skill was no longer used.) In other words: Meditate for a few months and the brain starts to rewire itself; quit meditation for a few months and the brain might well fall back to its baseline premeditation state. This assumption is easy to test; all we need is a scanner, a good amount of money, and two groups of people: Folks who persisted with MBSR (or a similar course) after the program is over and folks who are willing to confess that they did not. Right now, we don't know.

The Positive Side Effects of Meditation

Most—although possibly not all—of the differences in brain morphology that I have described so far make sense: We can understand them as the brain responding to the demands of meditation. Pay close attention to the sensations in your body and your brain will sharpen the pathway from the representations of the bodily sensations to the attention centers. Let go of the story you build around yourself and your precuneus will shrink a little. And so on. In other words, the changes may correspond to your increasing experience with meditation.

There are also, however, a few studies that show intriguing side effects of the brain changes that come with meditation—positive changes in aspects of behavior that have little to do with the stated goals or demands of meditation, at least as it is typically practiced in a Buddhist context. Here I concentrate on four examples.

The first example, also mentioned in the previous chapter, concerns the brain's response to **pain**. As all of us who have ever meditated know, pain is part of the reality of sitting still on a cushion for a long time. But we don't meditate, of course, to get rid of the pain that meditation causes (that would be a bit, well, circular and unproductive). Still, this seems to be what happens: In the previous chapter, I mentioned that meditation makes (literally) painful experiences less unpleasant. I discussed a number of mechanisms that could explain this effect. One of these is reexamination, which helps dampen the emotional response. We saw that there is some evidence that the salience network is involved in this endeavor. And, of course, the salience network changes with meditation experience, as we saw earlier—the anterior cingulate cortex and the insula grow in volume and/or density.

In one study, Joshua Grant and colleagues[34] looked at this meditation–salience network–pain connection directly, in 19 Zen practitioners and 10 nonmeditators. They put a thermode—a device that generates heat—on the left calf of each participant, heated it up, and asked how painful the sensation was, on a scale from zero to 11. They wanted to measure the experience of moderate pain, which they defined as 6 to 7 on that scale. They found that meditators were less sensitive to pain—their threshold for moderate pain was at 50.1°C (122.2°F), that of nonmeditators at 48.1°C (118.6°F).

Looking at brain morphology, they found that the size of the dorsal anterior cingulate showed a correlation with meditation experience—people who practiced meditation longer had a thicker anterior cingulate cortex. Interestingly, they found that pain sensitivity was also related to volume in this brain region, as well as a few others—the dorsal anterior cingulate cortex, the hippocampus, the secondary sensory cortex, and the insula[35]: thicker cortex, lower sensitivity to pain. What is happening here, it seems, is that the experience of repeatedly checking in on your sensations, thoughts, and emotions during meditation builds a brain that is also well equipped to deal with pain.

The second example concerns **personal well-being**. You would imagine that quite a number of people meditate to feel better about themselves and their world, but it isn't something that is typically deliberately practiced during meditation. Omar Singleton and colleagues[36] found a direct meditation–brain–behavior relationship, much like the relationship Grant et al. found for pain. In this case, meditation led to higher gray matter density in a few particular regions of the brainstem,[37] which in turn correlated with meditators' self-reports of well-being.[38] What is particularly important and exciting is that this study was an intervention study—an eight-week MBSR program—and that the key finding was that brain *changes* over this relatively brief period correlated with *changes* in well-being, just about as strong an indicator of causality as you can get with this sort of design.

The third example concerns **self-perceived stress**. Note that self-perceived stress is not about the daily hassles or important life events that actually happen to you (psychologists call these "stressors" rather than "stress") but about how you handle these—your feelings, thoughts, and behaviors in relation to those experiences. It is possible to quibble about whether changes in self-perceived stress are a side effect or a direct effect of meditation. One could argue that the effect is direct, that is, intended, because meditation instructions often do emphasize the calming nature of meditation. On the other hand, rarely do they involve asking meditators to handle stressful situations then and there, on the cushion; in fact, most meditation traditions I know of would explicitly discourage analytical thinking about your life issues during meditation time. Either way, in one intervention study[39] with a standard eight-week MBSR program, changes in gray matter density in the amygdala were associated with changes in self-perceived stress—larger decreases in volume in the amygdala were associated with larger decreases in perceived stress.

Finally, one study[40] found meditation–brain–behavior effects on **mood**. Like personal well-being, an improvement in mood is something people might expect as a result of their practice, but mood enhancement isn't explicitly part of the meditation training. After a four-week training in an MBSR-like program, changes in the left sagittal stratum and corona radiata (both are white matter tracts) correlated with changes in mood—people with newly strengthened neuronal connections described themselves as feeling less angry, less confused, less dejected or depressed, and less tired or lethargic. Both pathways have been implicated in depression,[41] so it makes sense to expect that changes in their efficiency would lighten mood.

In sum, there are some indications that practicing meditation has an impact on specific brain structures, which in turn leads to positive side effects. In two cases, the side effect aspect seems clear: The practice of one skill (vigilant monitoring) likely leads to brain changes (growth in the anterior cingulate cortex and changes in the corona radiata), which then in turn lead to side effects (lowered sensitivity to pain, improved mood). In the two other cases (stress and well-being), the reason for the brain changes is less obvious, and the observed changes weren't on Fox et al.'s map.

Again, I end with the cliché that we need more studies. One reason is that none of the studies cited here have been replicated. It would be good if they were, so we can be certain that the results are not some odd, one-time occurrence. (Randomness happens.) Another reason is that what are truly side effects from a strict point of view are often effects that for at least some meditators are the real deal. That is, people who start meditating often do so because they have heard it might help them with stress or might help improve their mood. If these side effects are a natural consequence of the way meditation is practiced, we don't necessarily need to change anything in our curricula to accommodate meditators with such goals and desires. If, however, stress reduction or mood improvement are not a direct consequence of the type of attention training that is the focus of most meditation programs, it might make some sense to see if we can find a more direct route for those seeking this kind of relief.

Meditation Shaping the Brain: A Few Conclusions

The main conclusion from the studies I have reviewed here is that meditation indeed seems to shape the brain. Specifically, meditators show measurable differences in gray matter in areas associated with attention, global and specific body awareness, the quieting of the self, emotion regulation, and a better regulated stress response. They also show stronger interconnections within the brain, back to front and side to side. Meditation even seems to have some anti-aging effects. There are dose–response relationships, suggesting that at least some of these brain changes are due to meditation per se, and there is some preliminary evidence that some of these changes may become visible after only eight weeks of mindfulness training. These changes lead to some desirable side effects—lowered pain sensitivity, heightened well-being, lower stress, better mood.

Throughout this chapter I have indicated further avenues for research. There is a lot we do not know: There is the puzzling finding that differences between meditation orientations do not seem to matter much; we still have a limited grasp on changes in white matter tracts; we know nothing about the sequencing of effects (Do white matter changes precede gray matter changes? Do changes in attention networks precede other changes?); we know nothing about dose–response relationships in the executive control attention network, in the areas associated with global body awareness, and in those associated with the narrative self; and we have little direct and hard evidence that the desirable side effects are indeed direct and inevitable consequences of the attention-related aspects of meditation practice. The presence of publication bias in morphology studies remains troubling, especially given that there is no exact correspondence between the results from cross-sectional, longitudinal, and dose–response relationships. Finally, we know a lot less about how these brain changes inscribe themselves into behavior than we should.

In the next few chapters, I investigate the behavioral changes that come with mindfulness and meditation in more depth. Chapter 5 looks at the intended effect of most types of meditation, namely a sharpening of attention. Chapter 6 takes on the changes in stress, sleep, and well-being, and Chapter 7 investigates the usefulness of mindfulness as therapy or medicine.

{ 5 }

From Monkey Mind to Monk's Mind

MINDFULNESS PRACTICE AND ATTENTION

In the previous chapter, we saw that more permanent changes in the meditating brain include gray matter changes in regions associated with the salience network and the executive control network, general body awareness, emotion regulation, the stress response, and the linkages between them. From this, we might expect changes in corresponding properties of heart and mind—sharpened attention perhaps, improved vigilance, changes in body awareness, maybe changes in personality and how you experience your self, maybe an enhanced capability to deal with negative emotions and life's small (or even larger) frustrations.

As we saw in Chapter 1, modern Western definitions of mindfulness highlight the concept of attention: Mindfulness is "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally"[1]—from the point of view of mindfulness, everything follows from following the breath.[2] It makes sense, then, to first look at how mindfulness training impacts attention before we look at changes in other aspects of a person's psychological make-up.

Note that we are switching methodological gears again. Studies probing the meditating brain in action (Chapters 2 and 3), as we saw, mostly test very long-term Buddhist meditators (many of them nuns or monks). Studies on structural changes in the brains of meditators (Chapter 4) all used laypeople, but still about half of them practiced within a religious, Buddhist context. On average, these people had less than half the lifetime experience of the volunteers in the brain activation studies; these studies also included participants from "secular" (or, if you prefer, "clinical") meditation programs—MBSR or MBSR-like.

The set of studies in this chapter lower the meditative achievement of the average research participant a little more and have a much higher proportion of participants from these secular programs. Part of the reason for this shift is pragmatism on the part of researchers: Such volunteers are generally easier to find, and it is now perfectly feasible to include them in these studies. That is, testing people on attention or other psychological measurements in a psychology lab doesn't require people with the amazing feats of unshakeable meditation required for the studies in the previous chapters.

This shift, of course, makes it hard to directly link the studies on attention to studies on the meditating brain—this is a different group of people, with a very different level of experience. We simply don't know if the changes in attention we observe in these less experienced meditators bear any relationship to the changes we've noted in the brains of the very advanced practitioners. On the other hand, the research volunteers here look a lot more like me and (perhaps) you, and so the results from the studies in this chapter are more likely to be applicable to the average practitioner of mindfulness. Our brains might not necessarily look like nuns' or monks' brains (frankly, we don't know), but our feats of attention likely look like the ones covered in this chapter.

As in previous chapters, my emphasis here—all in the service of avoiding bias—is on looking at results of batches of studies on a particular topic, preferably relying on results from meta-analyses, rather than zooming in on one particular study.

Meditation and Three Aspects of Attention

The largest meta-analysis on the psychological effects of meditation is by Peter Sedlmeier and colleagues.[3] This analysis gathered a total of 163 studies that examined the effects of meditation on all kinds of psychological variables. All of these studies compared performance of a group of meditators (who could be either seasoned or beginning, or anything in between, but most of them were fresh out of an MBSR-type program) with that of a group of control subjects, that is, people who do not meditate. They found 22 studies that focused on attention. The average effect in these studies was 0.58 *SD*, which is quite respectable. It implies that the average meditator is more attentive than 72% of nonmeditators. In a follow-up study, Ebert and Sedlmeier[4] refined the Sedlmeier et al. analysis to include only studies on mindfulness meditation (in practice, that meant removing all studies on Transcendental Meditation® from the larger meta-analysis); the remaining eight studies had a very similar effect size—0.63 *SD*. The average mindfulness meditator has stronger attention skills than 73% of nonmeditators.

Attention, of course, is not a single skill. It's quite different to focus your attention on just one thing and exclude all distractors than to remain sharp and concentrated for a long time, and it is different still to divide your attention between two or more tasks at the same time. In Chapter 3, I introduced a model devised by Wendy Hasenkamp and colleagues[5] that captures the different types of attention engaged in meditation well: It starts with the inevitable cycle of mind-wandering (a lack of control over attention), which is punctured by the awareness that you are mind-wandering, followed by bringing your attention back, and finally sustaining it for a while—until your mind wanders off again. Attention here, then, serves three functions.

The first is *noticing and alerting*, that is, detecting when the mind wanders; this function is associated with the salience network. Note that Kabat-Zinn's definition highlights a particular *quality* of this noticing and alerting attention, namely a sense of openness and lightness (the "nonjudgmentally" in his definition). This is an aspect of attention that is not typically studied by psychologists.

The second is *controlling* attention, that is, returning your focus to where it should be; this function is associated with the executive attention network.[6] This aspect of attention is also often called "concentration."

The third function is *sustaining and stabilizing* attention, that is, keeping awareness focused on what it needs to be focused on; this is done by a subset of the executive attention network.

It makes sense to group studies according to these three categories. I examine the evidence for changes in attentional control first, because most studies on the effects of mindfulness and meditation on attention have focused on this particular aspect.

The Effects of Meditation on Controlling Attention

Psychologists use many tasks to measure attentional control, but the one that is perhaps most popular is a simple, yet devilish little test I introduced you to in Chapter 2—the **Stroop task**. Recall that in the Stroop task you are shown a series of color words (words like "red," "green," etc.). Each word is printed in a different color than the word it refers to (e.g., the word "red" can be printed in green, the word "green" may be in blue, and so on). Your task is to name the color of the ink, not the color the word refers to (so, in the previous example, you would say: "green," "blue," and not "red," "green"). This is hard—it slows you down, and you might make a few errors, maybe even producing blended words like "bleen" or "grue." The reason this task is difficult is that reading is an automatic and "obligatory" process; that is, once you see a word or a sentence, you can't help but read it. (Try it: Next time you see a billboard, try *not* to read what it says. Can you do it?) This automatic process of reading the word interferes with you naming the ink color. To do well on the Stroop task, you clearly need to pay attention and stay focused on the task and go against your natural tendency to prioritize reading. The Stroop task is used so often because it works and because is very easy to administer—all you need is paper and a stopwatch (although it is now often done on computers), and it takes less than a minute.

I was able to locate nine studies on the effects of meditation and mindfulness practice on the Stroop test[7]; the total number of meditators involved was small—221. The average effect size for these eight studies was 0.45 *SD*. The average meditator does better on the Stroop task than 67% of the general public.

In three of the nine studies, participants were new meditators who learned to meditate over the course of the study (accumulating between 18 and 40 hours of experience); the effect size for these three studies was 0.42 *SD*. The other studies compared seasoned meditators (with typically a few years of experience) with nonmeditators; this resulted in a very similar effect size, namely 0.48 *SD*.

The similarity in effects suggests two things. One conclusion—very encouraging indeed—is that not much meditation practice is needed to increase concentration. Even 20 to 40 hours or so of practice results in measurable changes in control over attention.

The second conclusion is that you don't need to have many years of meditation practice to generate the kind of concentration needed for the Stroop. What matters more is the amount of daily practice. One study did find that the number of years of meditation correlated (rather modestly) with the Stroop effect (a correlation of –.27; people who had been meditating longer were less bothered by the color–word conflict), but the same study also found that how often you meditate had about the same effect (the correlation was –.23). (The first correlation can be explained by the fact that more seasoned meditators also tend to spend more time on the cushion.) Another study only found a dose–response relationship with the number of minutes practiced per day (correlation of –.17, again quite modest), not with total hours of lifetime meditation experience.[8]

Control can be measured with other tasks besides the Stroop task. I do not go into detail for all of these tasks here; I'll just mention one: the **go/no-go task**. In this task, you see numbers flash by on a screen, one at a time, at a fast clip. Your job is to press the button as quickly as you can whenever you see a number appear (that's the "go" part), except when you see a particular number, say, the number 2 (that is the "no-go" part). Being able to keep yourself from pressing the button when you are not supposed to is a powerful measure of how well you are able to control attention.

I found five studies on attentional control measures other than Stroop[9]; these yielded an average effect size of 0.23 *SD*. One study[10] found a strong correlation ($r = .52$) between the number of minutes practiced over the past eight weeks and how good people were at not making errors on a go/no-go task.

Combining the effect of all studies that included measures of attentional control (there were 10 of those), I obtained an average effect size of meditation on concentration of 0.39 *SD*, a lower number than reported in the two meta-analyses I cited earlier but still sizeable. The average meditator has better control over her attention than 65% of the general public.

The Effects of Meditation on Nonjudgmental Alerting

Kabat-Zinn's concept on nonjudgmental attention can be applied to more standard tasks of attention as well. Often, we look with an agenda, or we close off our minds prematurely. I would venture that paying attention in an open, nonreactive way would be an excellent example of this nonjudgmental stance.

One task that has been used to test the hypothesis that meditation experience might lead to a more objective, open-minded, nonjudgmental type of attention is the **attentional blink task**. In this task, you see a stream of about 20 or so letters, spit out one right after another on a computer screen at an impossible pace—typically 1/10 of a second for each of them. One or two digits are intermingled with the letters, and you simply press a button whenever you spot a digit. It turns out that when the stream contains two digits, people often miss the second digit when it is shown less than half a second after the first one. It is as if seeing the first digit causes you to mentally blink—hence the name of the task.

The standard explanation for the attentional blink effect is that you need to focus really hard to detect any digit to begin with. If you devote a lot of attention to detecting the first digit, you have no resources left for the second. To put this in terms of mindfulness: What makes you miss the second digit is that you are "stuck" on the first digit—too much investment, too much eagerness, too much "attachment" to doing it right (that is the judgmental mind, right there) and not missing that first digit. Unexpected confirmation for this account comes from studies where people are asked to do the task while they are being distracted by listening to music or viewing pictures—they do better when distracted than when they apply their full attention to finding the digits.[11]

Three studies have looked at attentional blink and meditation.[12] Two compared long-term practitioners with novices. They indeed found smaller attentional blink effects in meditators; the average effect size was 0.65 *SD;* the average meditator was less susceptible to attentional blink than 74% of nonmeditators. One of these two studies also compared attentional blink before and after a three-month retreat; the effect size, comparing attentional blink before the retreat with attentional blink after the retreat, was 0.38 *SD* in beginning meditators and 1.17 *SD* in advanced meditators.

If it is true that this decrease in attentional blink has to do with openness and nonreactivity, then you might expect that open-monitoring meditation, with its wider horizons, would lead to less attentional blink than focused-attention meditation, with its more narrow focus. Marieke van Vugt and Heleen Slagter[13] tested this with a group of 30 long-term practitioners of Zen, Tibetan Buddhism, or *Vipassanā*. They asked these participants to do the attention blink task while they were meditating in either a focused-attention or open-monitoring style (all participants were intimately familiar with both styles). They found that in the group of participants with the largest amount of experience (more than 2,600 hours), the attentional blink effect was indeed smaller during open-monitoring meditation, suggesting a less sticky quality to their attention. In the group with less experience (still on average 1,377 hours), however, there was no difference. This suggests that meditators can fine-tune the amount of nonreactive attention they bring to a task, but it also suggests that this ability takes some time to develop.

Other studies and tasks further show that meditators may have learned to pay attention in a more open, nonreactive way. For instance, one study[14] showed people the infamous **gorilla video** (if you have ever taken a Psychology 101 class, you've seen it—two group of students are playing basketball, you are asked to count the number of passes in one of the two groups, ignoring the other, and in the middle of the game, a man in a gorilla suit walks through the group of players; about two-thirds of people typically fail to see the gorilla). They found that meditators were 50% more likely to spot the gorilla than nonmeditators. They were also about twice as accurate in keeping count of the passes, suggesting that they were able to be focused and open-minded at the same time.

Another study[15] used a **startle-type task** (you may remember we saw one particularly compelling study of startle in one Tibetan monk in Chapter 3). You stand in front of a screen. At one point, a light turns on either to the left or the right; your task is to turn your head toward the light as fast as you can. Intriguingly, you will be faster at doing this when a blast of sound (coming from the center) is delivered at the same time as the light—one of the few examples where a distracting event can actually make you faster. The likely explanation is that the loud noise—if you let it get to you—gives you some extra boost of mental oomph. It turns out that meditators are less likely to speed up than nonmeditators. This suggests that meditators are able to just process the sound, without attaching a startling quality to it—it is just a loud noise.

A third study that demonstrates that meditators may have lower reactivity is one study on the Stroop effect we've already encountered in the previous section.[16] In this study, the researchers also recorded brainwaves. They were particularly interested in two types of waveforms. The first is the so-called **error-related negativity** (ERN; "negativity" here has nothing to do with anything bad—it's just that the electrical polarity of the brain signal is negative). The ERN typically happens right after you make an incorrect response (to be precise, about 1/10 of a second after). The signal likely comes from the anterior cingulate cortex, a part of the salience attention system, as we have seen. The ERN signifies that your brain has spotted that you have made a mistake—it is the brain going "oops." However, the presence of an ERN wave doesn't always mean that "you" will spot the mistake—even if you produce an ERN, you are not always aware that you just made an error. The awareness of making an error (your "Oh no!" response) is related to a second type of wave, the **error-related positivity** effect (confusingly abbreviated as Pe; again, positive here simply refers to the polarity of the brain signal). The Pe occurs a little later than the ERN, about 2/10 of a second after making an error, and it is thought to originate in the posterior cingulate, which is, as we have seen, part of the core of the default-mode network (the part that seems to get turned down during meditation). The researchers found that the ERN effect is larger in meditators than in nonmeditators and that years and frequency of meditation correlated with ERN as well (the correlation was .37 and .35, respectively), showing that meditators' brains are more alert to the mistakes they make. Interestingly, meditators did not show larger Pe values—thus their increased sensitivity to errors does not lead to stronger awareness of errors. That is, even though a meditator's brain quickly realizes and reacts to its mistakes, it is also very quick to let go of that reaction.

In a fourth study, Sara van Leeuwen and colleagues[17] showed people **local-global stimuli**, one at a time. A local-global stimulus is a large digit formed out of multiple identical small digits (e.g., a large 3 made up of tiny 8s). They asked their participants to press a button when they saw the digit 1 or 2, regardless of whether it was the global (large) or local (small) digit in the figure. Typically, people process the big, glaring global digit first, and so they are typically faster to report the 1 or 2 if it is a global digit than a local digit—in this study the difference was 56 milliseconds.[18] The study also included eight Buddhist monks and nuns; they showed less of a bias toward the global digit—for them the difference was only 21 milliseconds. This suggests that the monastics had more openness to what is really there, namely two different digits. Brainwaves were also examined, and it turned out that the meditators' brains showed stronger responses in the very early stages of processing, within the first 150 milliseconds or so,[19] suggesting a quicker uptake of information; they also showed larger engagement in the attention networks that are typically implicated in this task.[20]

We end this section with a small anecdotal finding from one study, done by Elizabeth Valentine and Philip Sweet.[21] They had people listen to 60 series of 2 to 11 bleeps; all they had to do was count the number of bleeps. The researchers note that many participants in the control group—the nonmeditators—commented on how *boring* this task was; none of the meditators did. This may, of course, simply mean that meditators are more polite or shyer to speak up than nonmeditators, but it may also mean that meditators meet their experiences with a different attitude, maybe with added openness. This, I find, is an interesting potential side effect of meditation worthy of further exploration: less boredom in daily life!

Let me note that another way of examining changes in this nonjudgmental attitude would be to give meditators and nonmeditators surveys that measure trait mindfulness. This has been done, and I report those findings in the next chapter, because they fit better in an overview of the subjective well-being side of things than in the objective tests of attention discussed in this chapter.

The Effects of Meditation on the Limits of Perception

Meditation manuals often imply that meditation will give you a more objective, accurate, and efficient way of looking at the world, maybe as a consequence of cultivating a nonreactive, nonjudgmental alerting mode of dealing with distractions in meditation. There are some reports that suggest that this may be the case.

One is the van Leeuwen local-global study I mentioned in the previous section. Another example is a study by Christian Jensen and colleagues.[22] They had people perform attention tasks before and after a standard eight-week MBSR training. In one of those tasks people read out letters that were flashed very briefly on a computer screen. By varying the duration each letter was flashed, the researchers were able to calculate how much time each participant needed to identify a single letter. Before training, it took participants 15 milliseconds to identify a letter; after MBSR, this was reduced to 9 milliseconds. Different control groups were included as well; neither of these improved in the speed of letter reading.

Likewise, Katherine MacLean and colleagues[23] tested seasoned meditators before, during, and after a three-month retreat and compared their performance with that of a no-retreat control group of equally seasoned meditators. The participants were shown two lines of different length, one after the other, and were asked to say which line was longest. The difference in length between the lines was varied so that the researchers could determine the minimum difference in line length that people are able to detect. Retreatants and nonretreatants did not differ in this minimum difference before the retreat, but retreatants were able to detect smaller differences between the lines both at the halfway point of the retreat and at the end of the retreat, as well at a follow-up session five months after the end of the retreat. There was a dose–response relationship: Those who spent more time in daily meditation during the after-retreat period could detect smaller differences between the two lines ($r = .36$).

These three studies, then, suggest that meditators have a faster and more precise uptake of what is out there in the world.

The Effects of Meditation on Sustained Attention and Attentional Stability

The third aspect of attention that is likely trained in meditation is the ability to sustain and stabilize your awareness on what it should be focused on. Psychologists typically gauge sustained attention by giving their participants very simple tasks. We could ask you, for instance, to look at letters passing by and press a button whenever the letter "k" appears. This is an easy task. The twist is that we make you do this for a very long time—typically 10 to 30 minutes in one go. This makes your time in the lab mind-numbingly boring. What is measured is how well you do at the end of the task, when you are terminally bored, tired, or both, compared to the beginning, when your mind was bright and fresh. Another way of measuring stability of attention is to stop you from time to time during these boring tasks and simply ask you if you were on task or not.

Maybe surprisingly, there is not a lot of research on meditation and sustained attention. I was able to locate seven studies.[24] Those yielded an average effect of 0.39 *SD*, on par with that for attention control and less than that for nonjudgmental alerting. Five of these studies used novices going through MBSR or an MBSR-like program; the average effect size was 0.33 *SD*. Two studies compared seasoned meditators before and after a three-month retreat (where the participants meditated for about 500 hours). They showed an average effect size of 0.60 *SD*, suggesting that an intense period of practice leads to a better ability to sustain attention. As far as I can tell, only one of the studies looked for a dose–response relationship; it did not find one.

Here I single out one additional study, done by Olivia Carter and colleagues, that used two rather exceptional tasks to measure stability of attention.[25] This study was exceptional for another reason as well: The research team traveled all the way to the Himalayan mountains in Ladakh, a region in northern India, to test Tibetan Buddhist monks living in exile there.

The first task they used was a binocular rivalry task. Binocular rivalry refers to a very curious sensation that happens when each of your eyes sees a different picture (e.g., your right eye sees a house, your left eye sees a face; to do this you can either use virtual reality goggles or, cheaper, red/green 3-D glasses[26]). You might expect that you would see a composite image—the face overlaid on the house, or vice versa—but that is not the case. Instead, what happens is that your awareness keeps switching between the two—now you see the face, then the house, then the face again, and so on. The two images tend to alternate every few seconds, with a brief period in between where you can feel the two images wrestle for dominance.

Why travel all the way to a remote region in India to show these images to monks? Well, attention appears to have an influence on the frequency of alterations: If you focus really hard on one image, you can keep it active in awareness a little longer. Carter et al. showed 23 monks binocular stimuli while they were meditating in one of two modes: focused-attention meditation or compassion meditation. Compassion meditation did not lead to any changes, as you might expect (the primary focus in this type of meditation is not on an outside object). Focused-attention meditation, however, did lead to slower alterations (i.e., more stability) in over half of the monks, both during and after the meditation.[27]

The second task Carter et al. included in this study was a motion-induced blindness task.[28] Motion-induced blindness is a visual illusion. You stare at a blinking green dot at the center of a computer screen that also has three yellow dots arranged in a triangle closer to the edge of the screen and a lattice of crosses that rotates. If you look intently enough, the yellow dots disappear after about 10 seconds (sometimes all three of them at the same time, sometimes just one or two). As soon as you relax your attention or move your eyes, the three dots reappear. The average student volunteer is able to keep the three dots from reappearing for 2.6 seconds. The average monk was able to do this for 4.1 seconds, or about 50% longer. More important, the duration record in the group of students was 6 seconds; 10 of 76 monks tested equaled or beat that record—one monk was able to stabilize the image for 128 seconds, and one even for 723 seconds. (This study also illustrates that the sustained attention effects that we have looked at so far, even in advanced meditators, are peanuts compared to the feats that true meditation experts are able to deliver.)[29]

Is It Attention or Is It Effort?

Attention—as you know—fluctuates. A slight cold or a bad night's sleep and it becomes hard to focus; nothing like a cup of coffee to perk you up. One psychological variable that influences attention is effort. (Psychologists call this "motivation to perform.") When you apply more effort to a task, you typically do better; when you make only a half-hearted effort, you'll likely not to do as well as you possibly could.

Some have criticized the studies on meditation/mindfulness and attention on this ground: It is possible that what changes is not attention per se but the amount of effort that people are willing to put into the task. Remember the Valentine and Sweet study, with the boring bleep counting task? In that study, nonmeditators remarked on how tedious the task was; meditators did not complain. It is then possible that meditators did better on the task not because their core capacity for attention increased but simply because their attitude changed. Maybe they were more motivated and thus more willing to invest effort.

One study, by Christian Jensen and colleagues,[30] tried to tease those two explanations apart. They compared participants in an MBSR program with a group of people who underwent a non-mindfulness–based stress reduction program and also with two groups of people who did not go through a stress reduction program at all. One of the latter groups was simply tested twice; the second group was offered $50 if they did better on the second test than the first test. For our purposes, it is the comparison with the latter group that is interesting—they had a clear incentive to apply more effort. (I can't speak for you, but I'd happily take $50 to do my very best on an hour's worth of attention tests!)

The researchers found that the MBSR group did better on tests of focused attention and on a visual threshold task than any other group. In contrast, they did as well as or worse than the $50 group on tasks that measured how well they could switch attention, return to the present moment, or be ready to react. This suggests that meditation may have an effect on focused attention and on visual perception that is not due to just effort. Effects on attention switching and on alertness are, however, suspect. Maybe MBSR-trained participants are more willing to invest the effort, perhaps because they want to prove the value of the treatment to themselves and/or the researchers.

One conclusion is that some of the effects of mindfulness and meditation on attention may be due to changes in effort, or the willingness to invest effort, rather than to changes in attention per se. You could also, of course, wonder if this distinction is truly important in day-to-day life: A change in your underlying attitude to life, especially an increased willingness to meet challenges with a bit more energy, seems like a vital part of healthy daily functioning to me. This, of course, would assume that meditators approach life in general with rejuvenated vim, and not just life inside the researchers' lab.

The Effects of Meditation on Paying Attention to the Body: Proprioception and Interoception

In many mindfulness traditions, paying attention to certain aspects of the body—the breath, the fleeting sensations that arise during a body scan, the sensations of how emotions actually inscribe themselves in the body—is a central aspect of the training. Given this central place of body awareness in mindfulness training, you would expect quite a number of studies on this topic. This is not the case, however. There aren't enough studies (for most of the topics falling under this heading) to warrant a meta-analysis, so I just briefly describe each of the studies and see if I can draw any meaningful conclusions.

First, the **breath**.

The one study that I was able to find[31] used two metrics. Participants were hooked up to a machine that registered their breathing—their nose was clipped shut, and they breathed into a mouthpiece that measured airflow. In a first task, the researchers added resistance to the air flow by placing little discs in the tube; they checked whether participants could tell whether or not the airflow was restricted. The answer is that people are quite accurate in this task, and meditators not more so than nonmeditators. In a second task, participants used a slider to indicate the frequency and depth of their breathing as they were hooked up to this machine. Meditators turned out to be a bit more accurate in matching the slider to their actual breathing. This, however, turned out not to be a meaningful difference. That is, meditators are also (as we have seen in Chapter 2) typically slower in their breathing, and this was true in this study as well. It is easier to detect and match slow breathing than fast breathing. When the researchers took this effect into account, meditators were no better at following their breath than nonmeditators. Note, of course, that the breath is typically easy to detect—this is actually one of the reasons it is so often used as the point of focus for beginners—so there isn't necessarily a lot of room for improvement after meditation.

The same cannot be said about **heart rate:** Those of you who wear fitness bands or smart watches with heart rate monitors know that heart rate is quite a bit harder to predict than breathing. Two studies[32] failed to show that meditators were better at heart rate detection than nonmeditators.

Two studies have looked at **sensitivity to touch**.[33] Kieran Fox and colleagues asked meditators and nonmeditators to indicate how sensitive each of 20 body regions (each of the fingers, the palm of the hand, the lips, the cheek, the nose, etc.) were; they correlated those ratings with what previous research has told us about these regions' sensitivity.[34] Nonmeditators showed correlations that were zero or negative, indicating that they cannot identify the relative sensitivity of parts of the human body. In contrast, meditators produced correlations between .31 and .46 (depending on the index of true sensibility), showing that they do know what areas of the human body are more or less sensitive. Accuracy (as measured by these correlations) also went up with the total number of hours spent in meditation (the correlation between accuracy and the logarithm of total number of hours of practice varied between .37 and .48, depending on the index of true sensibility); this increases the possibility that the increased sensitivity is due to meditation itself. Moreover, people who practiced body scan meditation did better (correlations between .41 and .64) than people who were novices in this particular technique (correlations between .06 and .18), suggesting that it is indeed paying attention to the body that drives this form of body awareness.

Laura Mirams looked more objectively at touch detection. A little vibrator was strapped to the participant's index finger; his job was to indicate when the vibrator vibrated. The vibrations were set such that they were barely detectable; on some trials, a light was also flashed near the finger, with or without vibration. In that case, people often mistakenly reported vibration when the only thing happening was that the light flashed. Students who had gone through a short (two-hour) body scan meditation program made fewer mistakes than before they were meditating and made fewer mistakes than nonmeditators. They also detected the real vibrations more easily. Thus even a very short meditation program can have some effect on touch sensitivity.

Meditation may also lead to better **coordination between seeing and acting.** José Raúl Naranjo and Stefan Schmidt[35] asked their participants to trace a line between two dots on a tablet. Participants couldn't see the actual tablet but were given visual feedback on a projection screen. Unbeknownst to them, the visual feedback was not completely correct, and so the angle of the line they were seeing was off. Three groups were included: long-term meditators (with, on average, 22 years of practice); a group of short-term meditators, tested before and after an MBSR program; and a control group of nonmeditators. The researchers found that long-term meditators were more accurate in line tracing, mostly because they slowed down, which made them able to be more deliberate in their movements. The MBSR participants were fast before the program and slowed down afterwards, resulting in higher tracing accuracy. The control group showed no changes. Thus mindfulness training seems to help people to control their actions better, and maybe even to select the best way of doing so, but doesn't necessarily really have an effect on the coordination between seeing and doing.

One study examined **self-reported body awareness** in daily life. In this study,[36] 152 participants in a three-month mindfulness program reported on eight different aspects of their so-called interoceptive awareness—the awareness of what is happening inside the body, often—in this case—with an emotional tinge. The researchers found that the answers of mindfulness-trained participants changed more than those of control participants for five of the eight aspects: Self-regulation (e.g., "When I feel overwhelmed I can find a calm place inside"); attention regulation (e.g., "I can refocus my attention from thinking to sensing my body"); body listening (e.g., "I listen for information from my body about my emotional state"); body trusting (e.g., "I feel my body is a safe place"); and emotional awareness (e.g., "I notice how my body changes when I am angry"). Aspects that didn't change were not-distracting (i.e., saying no to "I distract myself from sensations of discomfort"); not-worrying (i.e., saying no to "I start to worry that something is wrong if I feel any discomfort"); and noticing ("I notice changes in my breathing, such as whether it slows down or speeds up"). The average effect size, across the eight aspects, was 0.31 *SD*. Attention-regulation and self-regulation showed a dose–response relationship (the correlations between these aspects and total number of hours practiced were .18 and .22). Interestingly, the researchers found correlations between scores on the five aspects of body awareness that changed over practice and responses to questions that probed for how much the participants enjoyed the practice and looked forward to it—the more people enjoyed mindfulness exercises, the better they became attuned to their bodies, or vice versa (the correlations ranged from .30 to .43).

One reason this study shows a connection between body awareness and awareness of emotion might be an increased **integration between body awareness and emotional awareness**. Jocelyn Sze and her colleagues[37] monitored the heart rate of three groups of participants (meditators, dancers, and nonmeditators who also didn't dance) while they were watching a series of short emotional clips (depicting such things as a woman reacting to the news that her family members have died, a man chewing cow intestines, or a funny improv). The participants turned a dial to indicate their level of emotion (between negative and positive). The meditators showed the largest correlation between their heart-rate data (a good measure of physiological arousal) and their emotion ratings, followed by the dancers, who in turn did better than the nondancing nonmeditators. Thus meditators seem to be particularly good at tapping into the physiological markers of their emotions.[38]

Finally, the most researched aspect of the effects of mindfulness on paying attention to the body—this may surprise you—is increased **sensitivity to signs of sexual arousal**. The context here is the treatment of a specific type of sexual dysfunction in women, sometimes called "wanting to want"—having a lower sex drive than desired. Sexual arousal is an interplay between physiology and psychological factors—there is the bodily feeling of desire and the emotional oomph that (hopefully) accompanies it. It turns out that some women have difficulty connecting the two: While their bodies show signs of sexual arousal, their minds do not register the changes, and they remain emotionally unstirred.[39] Some have proposed that mindfulness could be very useful here, as it helps you to tune into your body. Additionally, mindfulness training stresses the suspension of judgment, which can be helpful as well—many women with sexual difficulties report that they associate sexual acts with concerns over performance, body image concerns, and/or partner and relationship issues, none of which are particularly helpful thoughts to have in that context.[40]

Most of the work in this area was done by Lori Brotto and colleagues.[41] The participants were women who were seeking treatment for sexual difficulties. The interventions in these studies typically consist of a two-week or four-week program combining mindfulness exercises (such as following the breath and a body scan) with education about diverse aspects of female sexuality (e.g., discussion of the female response cycle, discussion about the importance of sexuality in the participants' lives, and/or discussion of psychological influences on sexual behavior). The researchers measured how good participants were at judging their level of arousal, how much their ratings of arousal corresponded to physiological measures, or how they rated themselves on scales for sexual desire, sexual arousal, lubrication, sexual satisfaction, and overall sexual functioning. Average effect size for the three studies that included a control group was 0.63 *SD*.

All these interventions contain multiple components. How can we conclude with certainty that the mindfulness component was the crucial part of the mix?

One study[42] can help here. Brotto and colleagues compared a two-week mindfulness-based intervention (with an education component) to a two-week cognitive-based therapy intervention (with the same education component). They measured vaginal pulse amplitude (an objective, physiological measure of sexual arousal) while participants were watching an erotic movie; participants also used a computer mouse to indicate, moment to moment, their feelings of sexual arousal. The researchers found that mindfulness-trained participants became better at tracking their physiological arousal over time—mindfulness had helped them tune in to their body sensations. This was not the case in the cognitive-based therapy group. Unfortunately, this study included an extremely small sample—8 women in the mindfulness group and 12 in the cognitive-based therapy group—so the results can only be taken as suggestive, rather than definitive; they are nevertheless encouraging.

There are a few additional results that are noteworthy. First, at least two studies[43] found that mindfulness treatment in women (many of them suffering from low sexual desire, from failure to become aroused or to reach orgasm, or from pain during intercourse) led to higher levels of sexual and emotional intimacy, better communication with their partner, and more satisfaction with the relationship.

There is also some evidence that mindfulness treatment may be especially beneficial for women who have survived sexual abuse, maybe because it turns their attention inward, facing their own momentary sensations as they occur, rather than asking them to engage with their past, traumatic experience.[44]

Finally, one study[45] found a relationship between changes in trait mindfulness (as measured by the Five-Facet Mindfulness Questionnaire) from before to after a meditation program and changes in how quickly participants were able to judge their level of sexual arousal for erotic pictures (the correlation was .44—people who were more mindful were faster judges). Likewise, changes in self-reported anxiety correlated with changes in speed of judgments (correlation of .59—more relaxed participants were faster judges). This gives us a glimpse at the potential mechanism: Meditation makes you both more relaxed and more mindful, and this allows for more openness to erotic stimulation. It is quite possible then that this is simply another example of mindfulness practice creating a more open, nonjudgmental mind.

The Effects of Meditation on Timekeeping

An interesting often-noted side effect of mindfulness practice is a change in the practitioner's relationship to time—the present moment expands, and time seems to slow down. Why would that be?

One reason might be that your sense of time is related to how much attention you are paying to what is happening. This is true both for timekeeping (i.e., keeping track of time as it is unfolding now; e.g., I am brewing tea, and I need to let it steep for three minutes) and for looking back in time (e.g., how many hours did we spend on the beach yesterday?).

The best theory we have for how internal **timekeeping** works (at least for short durations) is that we have an internal clock. This clock has two parts: a pacemaker (the easiest metaphor is to image something that ticks, like, indeed, a clock) and an accumulator (e.g., a counter that keep track of how many ticks have been emitted)[46]. Two things influence this clock. The first is physiological arousal: When you are in a more relaxed state, the ticking goes slower. The second is attention: When your attention is focused on keeping time, you are more likely to collect all the ticks in the accumulator; when you are distracted or absorbed in something else, you might miss a few (or even a lot of) ticks. So if you are distracted, your accumulator will fill up more slowly; this means that the experience will be a little more timeless—time will run more slowly, which will make it seem as if it passes by more quickly. (In my own tea-making experience: If I pour the water and then lose myself in email, I will end up with a bitter brew.)[47] To quote Herbert Woodrow[48]: "Situations especially favorable to an experience that is subjectively timeless are those characterized by intensely absorbing occupations, such as reading an interesting novel, contemplating the beautiful hallucinations produced by some drugs, or battling for one's life."

Does meditation fit Woodrow's list? Two studies to date have compared timekeeping between meditators and nonmeditators[49]; one of those[50] found that meditators indeed underestimated time durations (i.e., meditators asked to press a button when they thought that, say, 8 seconds had passed were more likely to press the button after 10 seconds or so, indicating that the perception of time had slowed down); the other study,[51] however, did not. Two other studies looked at timekeeping right after a guided meditation of a few minutes; one[52] found that this slowed down time perception and the other[53] that it only did so in experienced meditators. The conclusion is that the evidence for a slowing down of time perception due to mindfulness practice leans ever so slightly in the direction that it might.

What about estimating **time duration in the past**?

The best theory we have for how we look back at time is based on memory: When you look back on an event or a time period (yesterday or last week), you retrieve memories from the event or the time period. If a lot of things happened to you during the event or time period, you are more likely to come up with more memories. If you come up with more memories, you will perceive the event as having lasted longer—filled to the brim. (For instance, if you spent yesterday afternoon at the beach soaking up the sun, you will estimate the duration as shorter than if you spent it playing beach volleyball, swimming, and running back and forth to the ice cream truck.)

There are (as far as I can tell) only two studies that have investigated how meditators look back at experiences. One study[54] had nonmeditators and participants in a mindfulness program watch a five-minute nature video clip while they were waiting for the experiment to begin; the experiment itself consisted of asking them how long they thought the video clip was. If they were more engaged with the video, or with their inner experience, they would experience more "events," and time would seem longer in retrospect. The meditators indeed thought the video clip was longer (4.14 minutes) than the nonmeditators (3.29 minutes). Essentially the same result was found (4.26 minutes vs. 3.73 minutes) when people were just left in the waiting room with no distractions and asked how long they thought they had been waiting, probably because meditators create more "events" by paying attention to their inner state and/or the outer world. Another study[55] used simple questionnaires to look at judgments of time. The researchers found that meditators felt less time pressure than nonmeditators (measured through answers on questions such as "I often think that time is running out") and had a more spacious sense of time (measured by questions such as "My time is filled"). The past week and the past month also went by more slowly for meditators than for nonmeditators. (There were no differences in the experience of the past year.)

These two studies, then, suggest that time gets filled more for meditators than for nonmeditators, regardless of what kind of external events fill the time. Another way of putting this is saying that, again, one of the side effects of a meditation practice may be less boredom.

The Effects of Meditation on Other Aspects of Cognition

It appears, then, that meditation sharpens and tunes attention across a wide variety of tasks and situations. Does it have an effect on other aspects of cognitive functioning as well? The short answer is that we still know very little about this.

Five studies[56] have looked at what psychologists call **working memory**. Working memory is the kind of back-of-the-mind memory that operates for a brief period of time—a few seconds. An example is you are having a conversation with a friend and something she says reminds you of something you want to say. While you wait your turn and focus on what you are supposed to be doing (listening to your friend), you stash away what you want to say in the back of your mind: That is working memory. Four out of the five meditation studies on working memory used beginners; all used relatively short interventions (on average 18 hours of meditation). The average effect over the five studies was 0.32 *SD*; the average meditator has a better working memory than 62% of nonmeditators.

The only other cognitive task that has more than a single study dedicated to it is **verbal fluency**. In a verbal fluency task, you are asked to come up with as many, say, animals or words starting with the letter S you can think of in the span of a few minutes. This may look like a straight-up test for your vocabulary, but it really is also a test of how smartly you can apply your attention. Take the "name as many animals as you can" example. Most people start off strong, rattling off all animals they can think of within a category (maybe pets); when they feel that category is exhausted, they typically move over to another category (maybe farm animals), and when that category is exhausted, they move to another one (maybe zoo animals), and so on. One trick to do well on this test is to jump to the next category as soon as the one you are working on runs dry; another trick is to figure out when that happens. Sometimes people get stuck trying to squeeze as many animals as they can out of a particular category and start repeating themselves, going over the same names again and again. The two studies[57] that have looked at the effect of mindfulness training on verbal fluency have found positive effect sizes—1.43 *SD* and 0.28 *SD*, respectively.

Finally, one study[58] found an effect size of 0.32 *SD* on the **verbal GRE**.

Meditation and ADHD

Given that meditation and mindfulness have what appear to be moderate effects on attention, it makes sense to ask if mindfulness interventions could be of use for people who show specific impairments in this domain. Mindfulness has indeed recently (the earliest published study dates from 2008) been used as a therapy for individuals with attention deficit hyperactivity disorder (ADHD). ADHD is a developmental condition, often continuing into adulthood, that affects about 3% to 5% of people in the United States and is characterized by frequent bouts of inattention (e.g., difficulty concentrating, difficulty sustaining attention, difficulty listening, being easily distracted), impulsivity (e.g., butting into conversations, difficulty awaiting one's turn, emotional outbursts), and hyperactivity (e.g., fidgeting, feelings of restlessness, running about, excessive talking).

There are no meta-analyses on the effects of mindfulness on ADHD,[59] but there is one overview article by John Mitchell and colleagues.[60] They were able to locate three studies on ADHD and mindfulness training in children and adolescents, five more in which children and adolescents participated with their parents, and nine studies on adults with ADHD—a modest harvest.[61] In total (and only counting people who went through treatment, not the control subjects), 294 individuals with ADHD were trained and tested, or an average of 17 per study (varying from 1 to 72). Eight of the studies included a control group; seven did not.

Most studies in this field are then what are considered to be "pilot studies," that is, studies that are done to quickly check if it makes sense to conduct a full-scale clinical study. (They are pilots in the old sense of the word: guides.) The goal of a pilot study is to see if the intervention is indeed successful (e.g., does it show an effect?) and also—equally important in early stages of clinical research—if the study can actually be done (do people like the intervention, or do they drop out? do people follow the instructions well? can the trainers handle what is thrown at them?).

The typical intervention in mindfulness-for-ADHD studies is about 8 to 10 weeks long. Many of these involve adaptations of existing curricula, like MBCT or DBT, but there are also programs specifically designed for treating ADHD with mindfulness principles: MYmind, aimed at children and adolescents and their parents,[62] and Mindfulness Awareness Practices for adults.[63] These programs combine education about ADHD with mindfulness exercises and practices. This, of course, makes it hard to gauge what the ingredients for success (if any) actually are.

A first conclusion from these studies is that mindfulness is a feasible intervention for ADHD—it can be done. Studies that note the participants' reactions mention that they find the intervention enjoyable, and the number of participants who follow the program all the way through is high—around 80% in the studies that report the numbers. This is encouraging indeed, because it is far from self-evident that people who generally have a short attention span and are quite distractible would enjoy the stillness of mindfulness activities enough to continue a demanding program for two or three months.

A second conclusion is that the studies show moderate support for the position that mindfulness is helpful to individuals with ADHD.

Let's first look at changes in self-report, that is, how individuals with ADHD describe their symptoms and experiences. In four out of five relevant studies, participants indicated lower levels of inattention after the intervention compared to before; in three out of three, they indicated lower levels of hyperactivity; in three out of four, the total number of ADHD symptoms declined; in three out of five, they indicated lower levels of depression; in one out of two, lower levels of anxiety were noted; in one out of two, the participants reported a lower incidence of "externalizing behavior" (i.e., acting out); and in three out of five, they noted an increase in quality of life. The score sheet is far from perfect, but these are, indeed, nice results.

Some studies also looked at other-reports, that is, assessment by parents, teachers, clinicians, or peers. The evidence is a bit more mixed in this case: One out of two studies noticed less inattention; two out of three lower levels of hyperactivity; and one out of two lower levels of depression.

Finally, scores on actual attention tests show an equally mixed picture. Studies including multiple types of measures often only obtained changes in a few (or none) of these (in two cases four out of 12, in another case one out of three, in yet another case one out of two; and there are three studies with null results: zero out of four, zero out of three, and zero out of one). Taken together, that means that across studies, we find six significant results out of 25 possible—a 24% hit rate. Clearly, this is not a slam-dunk.

One study[64] examined brainwaves. After the intervention, the researchers found an increase in error-related positivity in a go/no-go task, suggesting heightened awareness of errors. Changes in error-related positivity correlated with a decrease in hyperactivity/impulsivity symptoms and increased trait mindfulness. There was also an increase in a specific brainwave component (the P3) that is related to how strongly you engage attention; changes in P3 correlated with a decrease in inattention symptoms. Thus the intervention was associated with brain markers of attention during an attention task, and these changes also translated into an improvement of symptoms.

A final question concerns the duration of these effects. The results for adolescents and children are mixed—three studies[65] conducted follow-up at eight weeks; five out of eight measures that were found significant right after the intervention were also significant at follow-up. Encouragingly, what seemed preserved was mostly the gain on ADHD core symptoms. For adults, in all three studies[66] that included follow-up (at three months or six months), the gains that were found at the end of the intervention were still there at follow-up.

Taken together, these results seem promising. They suggest that mindfulness training can help ease the burden of the core symptoms of ADHD in a number of people. The results on objective tests are less clear-cut. All this work is still in the pilot stage. We need larger scale clinical studies with control groups to reach firmer conclusions; these would also help us get a good idea of the size of the effect.

Meditation and Attention: Conclusions

Meditation has an effect on all three forms of attention I have reviewed here: Its effect on focused attention is around 0.4 *SD*; a similar effect is noted on sustained attention; and there are also consistent effects on nonjudgmental alerting, with an effect size of 0.65 *SD* for attentional blink studies.[67] Meditators, especially those who practice body scan meditation, seem to have a keener sense of the body in terms of touch, better coordination between seeing and acting, and heightened body awareness in daily life; they are not better at detecting the breath or the heartbeat. Also, their sense of time expands.

I was particularly intrigued by the many studies that found evidence for nonjudgmental alerting, arguably the core aspect of Kabat-Zinn's definition of mindfulness—we see it in the attentional blink task, the gorilla video task, the (non) startle effect, the local-global effect, and in brain parameters like error-related negativity and positivity. Having so much converging evidence from so many different types of tasks is heartening. It is also interesting because this is an aspect of attention that is somewhat undervalued in standard cognitive psychology, where we are more interested in the amount or acuity of attention (how much can we take in, and how sharp do we see it?), rather than its quality. We often think of open-mindedness as something complex, an ability that operates at a high level of the mind (here I am, all open-minded!) and not as something that operates in a process as basic as paying attention and as a skill that can be trained. Two studies even suggest that meditation practice can help lower the threshold of perception, literally letting more of the outside world enter the realm of awareness. An interesting side note in this respect is the finding—in two different contexts—that meditation experience seems to make life a little less boring.

Attention is often considered the gateway to other aspects of cognition. Particularly, attention is important for working memory, helps with knowledge retrieval, and is important for real-life aspects of cognition (for which we saw only one example—GRE scores). All of these aspects of cognition indeed seem to benefit from meditation and mindfulness training, although the number of studies and the number of participants involved in each of these studies is still too small to allow for definitive conclusions.

Many studies underscore the importance of frequency or amount of meditation, rather than accumulated hours of practice. Frequent practice appears to sharpen the focus of attention, to alert you to mistakes, to broaden the limits of perception, and to help sustain attention. And, of course, the finding that eight-week MBSR programs can have a meaningful impact on attention, often on par with the effects seen in very seasoned meditators, underscores this point.

Finally, the attention-enhancing properties of meditation have led to promising clinical applications. There is early, encouraging but far from definitive evidence that mindfulness training might be helpful in easing the symptom burden of ADHD and quite good evidence that it may be beneficial for sexual dysfunctions that have their root in a lack of awareness of the physiological signs of arousal.

There are many open questions still.

First, one study investigated the role of attentional effort, arguing that what we are seeing in mindfulness-trained people is not the effect of the training per se but a newfound willingness to go the extra mile. That is a very good point, and it deserves further scrutiny.

Second, it would be great to know if there is an order to these effects—does one type of attention develop earlier than the other? Some[68] have claimed that changes in focused attention would come first and changes in sustained attention later, but I did not see much evidence for this position in the literature. The simple answer is that we don't know. We need an intervention study that looks at all three aspects of attention (and probably a few more cognitive and well-being type measures as well) and measures the effects repeatedly over the course of the training program.

A third open question is how these changes relate to changes in brain activation, and especially to changes in brain morphology—the link, so to speak, with the two previous chapters.

{ 6 }

Mindfulness Practice and Well-Being

I must admit that my own bias, as a cognitive psychologist, lies with the previous chapter—to what extent do meditation and mindfulness sharpen the mind; how far do they stretch attention? As we have seen, this question has attracted a good deal of consideration from the research community.

I would very much doubt, however—although I have nothing but anecdotal data to support this—that most people (me included) take up meditation because they hope it will help them focus. I also doubt they would stay with it if that was all it did (assuming it results in measurable daily-life benefits in that department—my graduate students, who bump into my forgetfulness on at least a weekly basis, like to believe otherwise). In the latest National Health Statistics report from the National Center for Complementary and Alternative Medicine (NCCAM), meditation is described as a "complementary health approach," and the authors say that "(t)his practice is believed to result in a state of greater physical relaxation, mental calmness, and psychological balance. Practicing meditation can change how a person relates to the flow of emotions and thoughts in the mind."[1] My guess is that most people practice meditation for these reasons—to get a deeper sense of calm and relaxation (in other words, to feel less stressed) and to upgrade their personal well-being.

One of the things that struck me in the NCCAM report is the turn of phrase: "This practice is *believed* to result . . . " [2] There is quite an enormous literature on meditation and mindfulness—surely we know by now?

The answer, as we shall see by the end of this chapter, is that we do know, in gross terms, but we still know less about the particulars of the workings of meditation than certainly I would like to know. Note that, in this chapter, I restrict myself to the effects of meditation and mindfulness on well-being in so-called nonclinical populations, that is, in people who aren't looking for relief from specific symptoms (e.g. anxiety) or specific syndromes (e.g., depression). I take up the question of the clinical effectiveness of mindfulness and meditation in Chapter 7—how mindfulness works as medicine for specific psychological problems rather than—as in this chapter—an enhancement of daily life.

Effects of Meditation, in Meditators' Own Words

Before I go into detail on the research on meditation and well-being (including its effects on stress), it might be good to hear from meditators themselves. What do they see as the primary benefits of the practice?

There is only one study I am aware of in which participants simply describe perceived benefits and drawbacks in their own words.[3] This study looked at 65 college students who took a semester-long meditation class. A large majority of the participants—85%—listed at least one benefit. About half of the participants (47%) noted increased **attention or awareness**, which was defined a bit more broadly than what we saw in the last chapter (e.g., "Better general sense of awareness," "Becoming aware of my breath again," "Staying in the moment with others," "To notice when I'm not being mindful'). Altogether, there were 31 reports of such benefits. But the large majority of benefits (112 instances) had more to do with a sense of ease and well-being: increased **calm and relaxation** (52% of the participants: "Being and becoming more calm," "More relaxed," "At peace with myself"), increases in **positive thoughts and positive personality traits** (26%: "Increased compassion for self and others," "Inserting love, kindness into thoughts," "Acceptance," "Letting go of unhealthy expectations"), **less anxiety and lower stress levels** (24%: "Less stress," "Get over stress easier," "Anxiety control"), **clear-headedness** (20% of participants: "If I distance myself from the details, things become clearer," "Able to organize my thoughts," "It helped me clear my head after a fight"), and/or **increased energy** (15%: "A new-found energy," "I felt refreshed and more ready to face the day," "A feeling of renewal").

This is a very encouraging list—it suggests that these participants may indeed truly be happier and more at peace after taking this class.

How to Study the Effects of Mindfulness on Well-Being

Sears et al.'s study nicely sets the stage for the type of effects we might expect from meditation and mindfulness[4]: positive impact on (a) stress and health; (b) sleep, fatigue, and relaxation; and (c) more emotional, personal, and interpersonal aspects of well-being (studies of this type have looked at negative and positive personality traits, affect, emotion regulation, self-compassion and self-acceptance, and compassion for others and empathy).

Note that we make yet another methodology shift in this chapter. The previous chapters used (mostly) "objective" or "third-person" measures, that is, effects that can be observed from the outside: changes in blood flow to particular areas of the brain, changes in the volume of specific brain regions, scores on a particular test for attention. Because those measures are objective, we mostly trust the measures themselves—disputes (if any) about these kinds of studies are usually about the number of people in each study (too small, as we have seen), whether the right kind of comparison group was used, or other issues of that nature. With the exception of some of the studies on health and stress (and a few choice others), we are now moving to "subjective" or "first-person" measures—measures where *you* indicate, by telling us or by taking a survey, how *you* feel, what *you* experience, or what *you* think.

One issue is that such subjective measures are more vulnerable to all kinds of biases, be they conscious or—as is probably more often the case—unconscious. For instance, if you spend a large amount of time meditating, you might want to convince yourself that you see benefits from your efforts, even if they aren't really there.[5] This is called effort justification (a process meant to reduce cognitive dissonance): If you invest a lot of time/energy/money in something, you assume it must be worth it.

Another possible issue is what psychologists call "demand characteristics." That is, when you know that you are a research subject in a study on the effects of meditation on well-being, and you really take to meditation and you really like the nice researchers who do all this stuff for you and for the greater good of humanity, you might give in to the subtle pressure (the "demand") and report that, indeed, you are now doing so much better.

A third possible issue is expectancy: If you believe that meditation works, this in and of itself can make you feel better.

Finally, subjective measures tend to be vulnerable to whatever is happening to you in the moment. If you woke up on the wrong side of the bed and I ask you how you feel about the past eight weeks of meditation, you will likely give a less favorable review of your experiences than if you are in an excellent mood.

The fourth of these problems will just make the data noisier; that is, it will introduce errors in both directions, positive and negative, and the first three might seriously skew the conclusions from a study. The only way to effectively deal with them is by using an **active control condition**, also known as a placebo condition or placebo treatment. What do we mean by that?

As I mentioned in Chapter 1, there are two ways in which the effectiveness of a treatment can be evaluated: as progress (e.g., do people feel less stressed out after having completed a mindfulness program compared to before?) and by comparison to other treatments or no treatment (e.g., is training in mindfulness a more effective way of letting go of stress than relaxation training?). In clinical-psychology parlance, the second type of comparison is called a "**controlled comparison**" or "controlled trial"—the word "control" refers to the comparison group, which in scientific lingo is called the "control" group.

Controlled comparison is the gold standard in any research designed to find out the effectiveness of a particular treatment—it is the only way to demonstrate that it is actually the treatment that causes the progress and not something else. Depression, for instance, often lifts by itself—if we simply note that the symptoms of depression get less severe over the course of an eight-week mindfulness program, it might be that all we are seeing is this natural progression (in at least some of the people) instead of a real benefit of the program.

There are two types of control groups: passive and active. Participants in a **passive control group** receive no treatment; they are simply tested twice—once before the mindfulness participants start their treatment and once after the mindfulness participants conclude their treatment. (Often these individuals are given the option to participate in the mindfulness training after they have done their job as control participants—this is called a wait-list control group.) Participants in an **active control group** receive some form of intervention that might be plausibly helpful. This treatment can be **specific**, that is, it is a known therapy—relaxation therapy[6] is popular—or it can be **nonspecific**, that is, it is not a known therapy but it matches the duration and level of attention people in the mindfulness program are getting—think health education or a support group. In the first case—comparison with specific treatment—we are interested in how well mindfulness works compared to something that we know works. The second case—mindfulness versus nonspecific active control—tells us something about the effects of mindfulness as a placebo. Placebo effects are effects that occur not because the treatment works but because participants trust that the treatment will work, be it due to expectancy, demand characteristics, or effort justification.[7] Placebo effects are often found in therapies for psychological difficulties. For instance, meta-analyses suggest that about 70% to 80% of the beneficial effect of antidepressants is due to the placebo effect.[8]

The gold standard in clinical research also involves **randomization** ("randomized clinical trials" or "random assignment" are key words to look out for). This means that when participants volunteer for the study, it is up to chance whether they receive the control treatment or the mindfulness intervention. The main reason for randomizing is to eliminate any possible bias in assigning people to interventions—otherwise researchers might stack the deck, consciously or not, and enroll people who they feel might benefit most from meditation into the mindfulness program.

Note that ideally all of these studies explicitly recruit participants interested in meditation and/or mindfulness, so that the participants are at least motivated to go through eight weeks of training. This is not always the case, however—I found at least one study that recruited participants for "a life style intervention program."[9] Vague recruitment could lead to smaller effects—as someone who participates in group meditation sessions and occasionally offers meditation instruction, I find that not everyone enjoys this activity in the long run.

With these short-term intervention studies, we are now moving even further away from looking at the effects of the kind of meditation practice for which we have brain data. This may be to our advantage, because it allows us a firmer grip on whether meditation and mindfulness are truly the forerunners of well-being. If we were to compare long-time meditators with nonmeditators and find that they are less stressed, some skeptic could always argue that maybe chiller people are attracted to meditation, or maybe only people who lead stress-free lives are able to stick with it. Do note, however, that not all studies included in this chapter used an intervention approach. Some did compare long-time meditators with nonmeditators; I will indicate when that is the case.

Effects of Meditation and Mindfulness on Stress and Health

Let's start our tour of studies on the effects of meditation and mindfulness on well-being with the aspect of well-being that is perhaps most clearly anchored in the body: resistance to stress.

When I typed "mindfulness and stress" into the PubMed online search engine, I was greeted by no less than 1,016 papers. (I admit I started hyperventilating a bit.) Then I remembered that the most popular mindfulness program—MBSR—has "stress" right in its name, and so not all of these papers were on the effects of meditation or mindfulness on stress. On the other hand, the name also reinforces the idea that the main goal of meditation for many is to live a less stressful life. More traditionally Buddhist approaches to meditation emphasize the place where it all starts—with the training of attention—while mindfulness training programs emphasize what it sees as the goal—stress reduction.

There are at least two review papers on the effects of mindfulness on **self-perceived stress**—one 2009 meta-analysis by Alberto Chiesa and Alessandro Serretti[10] (on 10 studies) and one follow-up paper by Manoj Sharma and Sarah Rush[11] that covers the findings since the Chiesa and Serretti paper (17 more studies), for a total of 1,555 mindfulness-training participants. All of these studies used some form of intervention, and all measured progress; some also compared changes in stress within trained participants with those in one or more control groups.

The groups of people investigated in these 27 papers aren't very random—13 of the studies had health-care professionals or health-care professionals in training as participants (a high-stress group if ever there was one), 4 used teachers, and 4 used undergraduate students; the rest were "community samples," that is, the general public. Most of the measures are self-report measures, that is, responses on a survey or questionnaire (the most popular is the Perceived Stress Scale, which asks questions such as "In the last month, how often have you been upset because of something that happened unexpectedly?" or "In the last month, how often have you found that you could not cope with all the things that you had to do?"); only three studies used a physiological measure. This isn't necessarily bad—what we call "stress" in common parlance is, after all, almost purely a subjective assessment. That is, stress isn't so much about what I have on my plate (technically, that is called a "stressor") as it is about how I deal with what's on that plate. For most people, public speaking is a major stressor, but those of us who teach regularly, for instance, have learned how to cope with that stressor and might even have figured out how to make it an enjoyable experience for all involved, including ourselves.

What are the findings?

Both review papers focus on changes from before the program to after completion. This is a fine way of looking at the findings—after all, when I go meditate, I am less worried about whether I will now be less stressed than, say, my colleague next door (a contest I could never win, because he is an extremely laid-back fellow), but more about how it tweaks my own personal stress levels. Chiesa and Serretti find that after mindfulness training, stress levels go down by 0.74 *SD*; in control groups (all but one of those were passive control groups), stress levels, in contrast, go up, by 0.21 *SD*—the net shift from before to after mindfulness training is thus close to one standard deviation. Sharma and Rush did not crunch the numbers, but they found positive change in 15 out of their 17 studies. So, yes: Mindfulness training clearly leads to stress reduction.

This is, however, not the way other researchers have meta-analyzed the findings I summarized in the previous chapters (i.e., those on brain function, brain structure, and attention), nor is it, as we have seen, the way clinicians typically look at the effects of therapy: There, the question is how meditators compare to nonmeditators—in this case, does having a mindfulness practice make you less stressed out than not having one? In the current group of studies, this amounts to a comparison between mindfulness-trained participants and the control group at the end of training. Keeping only the studies that contained a control group, and adding 12 further papers,[12] I arrived at a total of 27 studies, which yielded an average effect size of 0.36 *SD*; this implies that the average mindfulness-trained participant is less stressed than 64% of his nontrained counterparts. The seven studies that had college students as subjects resulted in an effect size of 0.31 *SD* (the mindfulness-trained student is thus less stressed than 62% of nontrained students at the same college); the 13 studies with health-care professionals or health-care professionals in training showed a very similar effect of 0.34 *SD* (the mindfulness-trained health-care professional is thus less stressed than 63% of her colleagues). Here too, then, the conclusion is that mindfulness training makes you less stressed, compared to living your life as usual.

Interestingly, three studies[13] included follow-ups after either six months or one year. Immediately after training, these three studies yielded an average effect size of 0.64 *SD*, which declined to 0.47 *SD* at follow-up. This suggests that the benefits wane a bit over time, but they are still significant and of medium size a few months after the training has ended. It would be nice to know if the participants kept up with their practice in between the end of training and the follow-up tests—if they did not, we have an easy culprit for the decline—but, alas, we do not.

Only one study, by Thaddeus Pace and colleagues,[14] examined the dose–response relationship, maybe more out of desperation than out of principle (they did not find a reliable effect of training), but what emerged was fascinating. This study is a bit atypical, in two respects. First, it is the one study in this group that used a heart practice—compassion training—rather than a strict mindfulness approach. Second, it included physiological measures of reactivity to a stressor. That is, the researchers measured how blood plasma levels of a stress hormone (cortisol) and a marker of immune functioning (interleukin-6 [IL-6]) changed as the participants (trained in compassion meditation, or not) went through what is one of the strongest stressors known to humankind: giving an oral presentation in front of a group of strangers. In this case, these strangers were all wearing lab coats and deadly serious facial expressions. As I just mentioned, and unfortunately for the researchers, there was no significant difference between trained and untrained participants on the stress measures. The meditating participants, however, also kept a diary record of their daily practice, and the researchers quickly noted that there was wide variability in the amount of practice: Some participants did only one or two meditation sessions per week on their own; others did seven or even eight. When the researchers looked at the relationship between the amount of practice and stress reactivity, they found that changes in IL-6 scores were tied to the number of times the meditators actually hit the cushion; the correlation was –.46, a good-sized effect. This suggests that there might be a direct effect: Meditate more and you will be less stressed.

Can we trace these effects back to changes in underlying **physiology**?

Interestingly, the usual suspect—**cortisol**, the key stress hormone—does not figure in this story, at least not as measured at rest. I am aware of three studies on cortisol and mindfulness training.[15] The average effect size across the three is –0.07 *SD*, which is not significantly different from zero. We did see in the previous paragraph, however, that one study suggests that the amount of recent practice influences how much IL-6 the body secretes as a response to a stressor. It may be the case, then, that under normal circumstances—at rest—meditators have similar levels of baseline calm or unrest as nonmeditators (as tapped by cortisol) but that they are less easily tipped off balance when a stressor does appear (as measured by IL-6). This is pure conjecture on my part; we definitely need more studies here.

Other studies do show effects of mindfulness training on physiological indicators of stress and health, notably on indicators of **immune functioning**. The most famous of these is by Richie Davidson and colleagues.[16] In this study, participants in an MBSR program and wait-list control participants were given a flu shot right after the conclusion of the mindfulness program. Four months later, they came back to the lab to be tested. The researchers found that the meditators had produced more antibodies against the flu than the nonmeditators, indicating a more efficiently working immune system (the effect size was 0.67 *SD*). The researchers also measured asymmetry in frontal brain activation using EEG. The reason for this is that some studies seem to suggest that people who activate the left part of the brain more than the right tend to have more "positive affect," that is, a sunnier outlook on life. Davidson found two remarkable things: After the training, the mindfulness-trained participants showed more left-frontal activation than before and more than the control participants, and there was a very nice correlation ($r = .53$) between the change in left-frontal activation and the amount of antibodies these participants produced. The natural interpretation here is that meditation makes people happier, which in turn might boost their immune system.[17]

Four more studies provide some confirmation that mindfulness has an effect on immune functioning, but three of those include individuals with a medical diagnosis that explicitly compromises their immunity. This is excellent for therapeutic purposes, of course, but less than ideal if we want to generalize the findings to nonclinical groups. Two of those studies[18] looked at HIV-positive men. Both found changes in immune functioning after an eight-week MBSR program compared to a control group. More specifically, they observed either an increase in NK cells (so-called killer cells; effect size = 0.86 *SD*) or stability (rather than the decline noted in the comparison group) in CD4+ lymphocytes (effect size = 0.16 *SD*). A third study looked at different aspects of immunity in survivors of breast cancer after surgery[19] (targeting killer cell activity, cytokines, and leukocytes); survivors who went through an MBSR program post-surgery did better on all of these aspects one month after completion of the program (effect size = 0.59 *SD*). Finally, one study[20] found greater telomerase activity (a predictor of long-term cell survival) in long-term meditators who had just finished a three-month retreat compared to long-term meditators who had not (effect size = 0.22 *SD*).

The average effect size over these five studies is 0.46 *SD*. Note that all of these studies, again, used small samples (25 people in the mindfulness group in Davidson et al.; 24 in Robinson et al.; 33 in Creswell et al.; 44 in Witek-Janusek et al.; 30 in Jacobs et al.), that the number of studies itself is small, and that—as stated previously—three out of five studies chose their participants explicitly because of a weakened immune system. For all these reasons, we should be very, very cautious before attaching grand conclusions to these findings.

Sleep Quality

Sleep can be considered an aspect of well-being—we all appreciative a good night's sleep. Does meditation and/or mindfulness help with that?

We could make two opposite predictions here. First, as we have seen in Chapter 2, meditation is sometimes considered to be a form of relaxation that—in some instances—looks like sleep. Second, as we saw in the previous chapter, meditation also clearly involves alertness, and it is, in effect, quite a powerful tool to improve attention, including vigilance and wakefulness.

From the first observation, we would expect that meditation might help with sleep problems, perhaps by making it easier to fall asleep, by increasing sleep duration, or by increasing sleep quality. This has led some researchers to use mindfulness and meditation as an intervention for **insomnia** (i.e., sleeplessness), whether caused by medical issues (e.g., pain associated with fibromyalgia), psychological problems (e.g., stress), or as a problem on its own. There are now two review papers on this topic,[21] covering a total of 14 studies, and the conclusions are not encouraging. Uncontrolled studies do show positive effects, but the data are all self-reported (using diaries or surveys), and controlled studies show largely no effects; that is, both the trained participants and the untrained participants show the same self-reported effects—usually beneficial. (Suggesting, perhaps, that simply participating in sleep research makes you a better, sounder, happier sleeper, at least in your own mind.)

When we look at objective measures—either studies where people are brought into a sleep lab or where they are given sleep monitors to wear at home—the second viewpoint appears to win. I was able to find four such studies.[22] On average, the meditators in these studies (three groups of long-term meditators and one group of MBSR-trained folks) slept half an hour less than the nonmeditators (6 hours and 7 minutes vs. 6 hours and 37 minutes; or 8% less); meditators were also awake for longer periods during the night (46 minutes vs. 38 minutes; or 22% longer), and they took just a little more time between hitting the pillow and falling asleep (8.6 minutes vs. 8.0 minutes). Sleep quality changed too, in the sense that meditators used sleep more efficiently: They spent less time in Stage 1 sleep—the shallow sleep that starts and ends a sleep cycle (43 minutes vs. 51 minutes, or 16% less), and more time in Stage 3 and 4, or slow-wave sleep—the deep sleep that is generally seen as the restful phase, where you recover from your daily activities and build memories (42 minutes vs. 31 minutes, or 36% longer).[23]

There may be a hidden dose–response relationship here: In Britton et al., the only study that included beginning meditators fresh out of an MBCT class, participants spent *more* time in Stage 1 and *less* time in deep sleep; moreover, within that group, people who did more home practice spent more time in Stage 1 (a correlation of $r = .80$), spent less time in deep sleep ($r = -.61$), and woke up more often during the night ($r = .57$). This possibly suggests that the effects vary with levels of meditation experience: Early in practice, your need for sleep decreases, and your levels of alertness and physiological arousal run high, causing you to wake up more often and sleep less deeply; later in practice, the body adapts to the wakefulness and makes the most out of the shorter sleep period. (I should note here too that Britton et al.'s participants were all depressed patients in remission, that is, people who were formerly depressed but now considered symptom-free who went through the MBCT program in the hope to prevent relapse. The changes in sleep pattern correlated with decreases in depression scores, and so it is possible that what we see in this study is actually a further improvement of the remaining depressive symptoms, rather than a direct effect of practice.)

Fabio Ferrarelli et al. report another type of dose–repose relationship. In that study, meditators showed stronger gamma oscillations in their brainwaves during non-REM sleep. What is really interesting is that these gamma oscillations occurred in the same brain regions where meditators often show gamma oscillations during the resting state and during meditation. The strength of these gamma oscillations correlated with the total lifetime number of hours of meditation practice ($r = .48$). Gamma oscillations are typically associated with executive attention. Ferrarelli et al. speculate that what might be happening is that over time (these participants had on average about 4,000 hours of accumulated practice) meditation becomes a habit (or, as psychologists say, a trait). Just like the resting state becomes more meditation-like with advancing practice (as we saw in Chapter 3), so too might sleep become more meditationesque—the meditation pattern simply seeps through all aspects of daily (and nightly) life. Or, as Britton et al. put it beautifully in the title of their review paper[24]: "Awakening is not a metaphor."

Emotional, Personal, and Interpersonal Aspects of Well-Being

Several studies consider the effects of meditation and mindfulness on emotional, personal, and interpersonal aspects of well-being—emotions and emotion regulation, personality traits, self-concept (I fit self-compassion under this umbrella), as well as empathy and compassion for others. Unfortunately, the number of studies that meet customary methodological expectations is much smaller than the actual number of studies that have been published. For instance, in the largest meta-analysis on the effects of meditation on psychology, by Peter Sedlmeier and colleagues,[25] the authors initially collected 595 studies. This number was eventually whittled down to 163, due—mostly—to methodological concerns about the remaining 432 studies. Most of these boiled down to the absence of a control group. This is bothersome, of course: Three-quarters of the published studies in the field simply don't meet the basic standard that would allow for scientifically valid conclusions.

In my overview here, I reanalyze part of the pool of studies collected by Sedlmeier et al.[26] The original pool included studies of types of meditation other than mindfulness meditation, such as Transcendental Meditation® or other forms of mantra meditation; I deleted those.[27] This leaves a total of 57 studies.[28] These cover a wide range of psychological variables, including some we have visited before, like stress (covered earlier in this chapter) or attention (covered in the previous chapter). Of the 57, 46 are intervention studies where absolute beginners were trained for, on average, 51 days (or about seven weeks; the shortest training took 10 days, the longest 154 days). The remaining 11 are studies looking at differences between nonmeditators and meditators; the latter boasted, on average, nine years of prior meditation experience. Average sample size was 55 people per study (3,154 participants total).

As you can imagine, there are many conceptualizations of well-being,[29] but often psychologists look at life satisfaction either in general or within different domains of life (well-being at work, in relationships, and so on) or in different aspects of life (emotional well-being, social well-being, and so on). In the next few subsections, I give an overview of work on those aspects of well-being that have been included in meditation/mindfulness studies: general quality of life, emotional well-being, and interpersonal well-being.

MEDITATION AND GENERAL QUALITY OF LIFE

There are a few questionnaires that try to capture well-being and quality of life as a general concept, using items such as "If I could live my life over, I would change almost nothing," "My daily life is filled with interesting things," or "Most of the things I do in the future will probably be . . ." (here the participants can choose between seven gradations, from completely fascinating to deadly boring). Sedlmeier et al. were able to locate five studies[30] that used such scales to gauge outcomes of meditation programs. The average effect size was a respectable 0.55 *SD*, indicating that the average meditator enjoys a higher perceived quality of life than 70% of nonmeditators.

MEDITATION AND EMOTIONAL WELL-BEING

Six studies[31] have looked at **state anxiety**. State anxiety is the type of anxiety that is temporary (psychologists call that a "state"). Such anxiety is often due to circumstances and how you react to them—feelings of nervousness, discomfort, or fear. For instance, when your airplane hits turbulence, you might feel nervous—that is state anxiety. Typical items used on surveys to measure state anxiety are "I am tense" or "I am worried." The effect size for state anxiety is quite large at 0.69 *SD*. After taking a mindfulness or meditation class, the average course participant is less state-anxious than 75% of nonmindfulness-trained people. My guess is that, like for pain, the skills of relaxation, refocusing, and acceptance come in handy when dealing with anxiety-provoking situations. (Next time you're caught in turbulence, just breathe.)

Eleven studies[32] have looked at **trait anxiety**—the kind of worry or fear or discomfort or being on edge that is part of your personality or that you experience on a day-to-day basis. Typical items to measure trait anxiety are "I worry too much over something that really doesn't matter" or the opposite of "I am a steady person." The effect size here is again quite large—0.62 *SD*—implying that the average mindfulness-trained participant is less trait-anxious than 73% of the general public.

I single out one particular study here, done by Peter Lin and colleagues.[33] Lin et al. studied a group of conservatory students (most of them were piano or violin students); they were interested in how meditation impacts performance anxiety during an actual recital. Performance anxiety isn't always bad—typically, there is a curved relationship, where either an absence or an overabundance of anxiety lead to flagging performance. If you don't care at all, you won't do well; if you care too much, you might literally get shaky—not a good thing for a precision sport like playing the violin. You need a medium, just-right level of anxiety. What this just-right level is isn't precisely definable: It is different from person to person, and it also differs by skill level. In the beginning stages of learning to play your instrument, a little anxiety can wreck you; when you get more adept, you will need higher and higher levels of anxiety to perform well.

In Lin et al.'s study, higher levels of anxiety were crippling on the recital performance of musicians in the control group, as you might expect. The newly minted meditators, however, played better and better as their levels of anxiety went up. The actual levels of anxiety and of performance did not differ between the two groups, so this finding is really about how the two groups deal with anxiety—how they transform it, so to speak, into musical energy. Meditators seemingly interpret the physiological signals of anxiety differently than nonmeditators. When nonmeditators spy the signs of anxiety in their body, they typically add psychological baggage to this—"Oh no, I am nervous. I will mess up!" Meditators may have learned to take a little more distance and to notice the changes in their body without getting caught up in them—"Oh, my heart is beating faster, I better concentrate on playing." This may allow them to channel their physiological arousal to focus on the task at hand: playing their instrument. Lin et al. cite one of the meditators, a jazz pianist, who mentioned that this was "the most relaxed I had been during a solo performance in a long time, despite the fact that I was still incredibly nervous (my hands were cold)." This student was clearly able to just observe and label what was going on, without letting the natural emotions associated with the physiological changes run their course.

Six studies[34] have looked at the effects of meditation on **depressed mood**, measured by items such as "I think my life has been a failure," "I have crying spells," "I do not expect things to work out for me," or "I am sad all the time." The average effect size is 0.32 *SD*, indicating that the average meditator feels less depressed than 63% of the general public.

There are six studies[35] that examined positive and negative emotions, typically with a particular scale called the Positive and Negative Affect Schedule (PANAS). This scale asks people either how they are feeling right now or how they have felt over the past week. As the name implies, it traces a set of positive emotions (i.e., do you feel interested, excited, strong, enthusiastic, proud, . . .?) and negative emotions (i.e., do you feel distressed, upset, guilty, scared, hostile, . . .?). Effect size for **negative emotions** was 0.41 *SD*; effect size for **positive emotions** was 0.54 *SD*—after mindfulness training, the average participant felt less negative than 66% of nonparticipants and more positive than 70% of nonparticipants.

Nine studies[36] have looked at **emotion regulation**. Emotion regulation refers to the ability to keep emotions in check as required by either the situation or your own personal goals. For instance, your boss might say something negative about your work performance; it is then probably a good idea to hold back a little and not to tell your boss exactly how you feel about that. Emotion regulation typically also includes being able to label your emotions and understand where they are coming from (just like the jazz pianist in Lin et al.'s study did). Items that measure emotion regulation are "When I'm upset, I feel like I can remain in control of my behaviors," "I am rarely confused about how I feel," or the opposite of "Whenever I am in a bad mood, I'm pessimistic about the future." Emotion regulation can also be measured in the psychology lab, as we have seen in the previous chapter, for instance by trying to interrupt someone's concentration by showing them emotional pictures or playing emotional sounds. The average effect size for emotion regulation is 0.34 *SD*, implying that the average mindfulness-trained participant is better at emotion regulation than 63% of nontrained individuals.

Rumination is a concept that is related to emotion regulation. Rumination means the rehashing of the same thoughts over and over again (usually these are negative thoughts), often with the sense that you are powerless to stop yourself from thinking them. Sample items are "When I feel depressed, I think about my shortcomings, failings, faults, mistakes," "Sometimes it is hard for me to shut off thoughts about myself," or "I find myself replaying events over and over in my mind." Rumination tends to get a foul mood going—as you can imagine, revisiting your shortcomings and failures over and over again is not exactly conducive to happiness. In a meta-analysis,[37] the correlation between rumination measures and negative affect was found to be 0.48. Depressed patients who ruminate more stay depressed longer,[38] and in random undergraduates, ruminators are more likely to get depressed over the course of their college career.[39] All of this suggests that it would be better for your well-being not to ruminate too much. There are four studies on meditation and its effects on rumination in the Sedlmeier et al. data set; the average effect size is 0.39 *SD*,[40] indicating that the average meditator ruminates less often and/or less vigorously than 65% of nonmeditators.

MEDITATION AND PERSONALITY

Second, there is some but not a lot of research on **personality** changes after training in mindfulness meditation.

There are only three studies[41] that look at what Sedlmeier et al. call **negative personality traits** (viz., egoism, dominance, psychoticism, rigidity, and capacity for status[42]). They show large effects: 0.89 *SD*. This is a nice outcome—a little more kindness, a little rounding off of rough edges, and a little less alpha-male behavior can make the world a better place for the people around you. The effect size implies that the average meditator scores lower on these negative traits than 81% of the general public.

One personality trait that has been examined a few times[43] (four studies in Sedlmeier et al.[44]) is **emotional stability**—that is, how good you are at maintaining your emotional balance, how even-keeled you are, how unlikely you are to be rattled or shaken by events. In classical personality theory, this is considered the opposite of **neuroticism**. Good examples of items probing for emotional stability are “I am relaxed most of the time,” “I am not easily frustrated,” or the opposite of “I have frequent mood swings” or “Sometimes I feel just miserable for no reason.” The average effect size is a modest 0.26 *SD*, and this was not significantly different from zero; meditators are less easily ruffled than 60% of the general public.

Practicing mindfulness also appears to have effects—as you would hope it would—on **trait mindfulness**.[45] Trait mindfulness (as discussed in Chapter 1) is measured with questions such as “I watch my feelings without getting lost in them,” “When I take a shower or bath, I stay alert to the sensations of water on my body,” or the opposite of “I rush through activities without being really attentive to them.” This is a popular outcome variable, for obvious reasons; Sedlmeier et al. found 16 studies[46] that measured it. As expected, trait mindfulness is higher in meditators than in nonmeditators; the effect size is 0.72 *SD*. Thus the average meditator is more mindful than 76% of nonmeditators.

One particularly interesting study on trait mindfulness was done by Laura Kiken and colleagues.[47] In this study, participants in an MBSR-like program received weekly emails; the email provided a link to a questionnaire on state mindfulness,[48] which the participants were asked to fill out right after completing a 10-minute version of the mindfulness practice of the week (e.g., body scan, mindful breathing, mindful movement, and so on). The answers on this survey thus indicate how good the participants indicated they were at being mindful during a mindfulness practice. The researchers then charted how each of the participants progressed in state mindfulness over the course of the eight weeks. They found that some people indeed made better progress than others. The interesting part was that the rate of progress in state mindfulness over the eight weeks of the program predicted the change in trait mindfulness from before to after the training. It also predicted the change in psychological distress. This suggests some form of translation process: When you practice your mindfulness practice more mindfully, this eventually translates into changes in trait mindfulness as experienced in life off the cushion. (Again, this is what one would expect and hope for—it is nice to see this expectation confirmed in research.)

Finally, seven studies[49] have looked at different aspects of the **self-concept:** self-acceptance, self-compassion, and "internal locus of control," that is, the feeling that the events in your life are mostly due to your own actions. All of these traits indicate a more positive and/or empowered view of your self. To give a few examples of items: People who score high on self-acceptance are "confident" and "present themselves with conviction"; self-compassion would be measured by "I try to be loving toward myself when I'm feeling emotional pain," or the opposite of "When times are really difficult, I tend to be tough on myself"; and people high on internal locus of control would endorse statements such as "When I make plans, I am almost certain that I can make them work" or "In my case, getting what I want has little or nothing to do with luck." Taken together, the seven studies have an average effect size of 0.66 *SD*, indicating that the average meditator has a more positive, stronger self-concept than 75% of nonmeditators.

MEDITATION AND INTERPERSONAL WELL-BEING

There is almost no research on the role of meditation practice in **interpersonal attitudes and skills**. Sedlmeier et al. found one study[50] that measured self-described social skills; the effect size was a whopping 1.58 *SD*.

One other study, by James Carson and colleagues,[51] looked at **couples** going through mindfulness training together and how that impacted their functioning as a unit. The participants filled out a number of questionnaires and also kept daily track of, among other things, their relationship happiness, their relationship stress, and how they dealt with the latter. Mindfulness had a positive impact on relationship satisfaction (items like "We have a good relationship" or "My relationship with my partner makes me happy"), autonomy (e.g., "My partner encourages me to follow my own interests" or "My partner thinks it's okay if I disagree with him/her"), and closeness (e.g., "My partner talks over his/her problems with me" or "My partner asks me to share things he/she enjoys") and made the couples more accepting of their partner (e.g., the rather complexly worded item "Considering characteristics of your partner, or your relationship, which you find difficult to deal with, over the last 2 months how easy has it been for you to stop struggling and just allow such things to be?") and decreased relationship distress (e.g., "I am pretty discouraged about our relationship sometimes," or the opposite of "My partner and I seldom have major disagreements"). The average effect size across these measures was 0.50 *SD*, suggesting that mindfulness-trained couples have a stronger relationship than 69% of nonmeditating couples. The benefits remained three months after completion of the program.

What I found intriguing in this study was that mindfulness practice had its effects on an almost day-to-day basis: On days when the participants practiced more, as well as on the next few days, their levels of relationship happiness went up and their levels of relationship stress (and stress in general) went down. This is good evidence for the direction of the relationship between mindfulness and relationship stress: It's the practice that drives the reduction in stress and increase in happiness, not the other way around.

Another interesting additional point was that, in the nonmeditating couples, confidence that they were able to deal well with stress ("Please indicate how successful you were in coping with all types of stresses today") was tightly in line with their relationship stress and overall stress: When there was more stress, confidence in being able to deal with it plummeted. In other words, the nonmeditators only felt confident in their relationship as long as it was going well. This association was gone in the meditating couples—they were less reactive to the daily hassles in their world, likely because growing mindfulness allows for just that little bit of emotional distance.

Two studies[52] investigated **empathy**. Empathy is the ability to understand someone else's emotional experiences (e.g., "As a rule I have little difficulty in putting myself into other people's shoes," "I feel other people's pain," or "If someone gets upset, I get upset too."). The average effect size over these two studies is 0.82 *SD*, implying that the average meditator is more empathetic than 79% of nonmeditators.

Empathy isn't always a good thing. It can lead to what psychologist call "empathic distress"—sometimes you can so strongly resonate with someone else's pain and suffering that you actually feel that pain and suffering yourself. Studies[53] suggest that this empathic distress actually leads to *less* helping behavior: It paralyzes you.

Here is where **compassion** can be useful. Compassion is more than a feeling[54]—it is accompanied by the motivation to help.[55] Surveys for compassion contain items such as "If I see someone going through a difficult time, I try to be caring toward that person" or "I spend a lot of time concerned about the well-being of those people close to me."

Psychologists have also devised sneaky ways to measure compassion in action in the lab. One way is having individuals play an online game[56]—called the dictator game—with a few strangers who are, unbeknownst to the participants, both computer-generated. There are many versions of the game, but the basic idea is that there are three players and a small stack of real money. In the first round, Player A plays the role of the dictator and is given $10 to distribute between herself and Player B. She gives Player B $1, keeping $9 for herself. In the second round, Player C becomes the dictator, endowed with $10. In one variation, Player C is asked to share with Player B (i.e., Player C can now ease Player B's financial suffering). In another variation, Player C is asked to share with both Player A and Player B. In this case, Player C has a chance to both ease Player B's suffering and punish Player A, if he is so inclined. What would you do?

Especially within the Tibetan Buddhist tradition, there is the conviction that compassion needs to be explicitly trained; it isn't something that automatically follows out of the mindfulness practices of focused attention or open monitoring. It seems that, maybe for that reason, compassion has not been much on the radar of researchers looking into the effects of mindfulness meditation. Sedlmeier et al. does not include it in his analysis; leafing through the stack of original articles that he collected, I found no study that measured it.

I did discover four studies[57] that explicitly trained people in compassion meditation and measured the effects of this training on some measure of compassion[58] and one[59] that compared practitioners well versed in compassion practices with novices in this practice. Compassion meditation programs typically start by building focus. In the next step, they introduce different concepts from the Tibetan compassion tradition known as *lojong* and ask participants to reflect on those in a meditative state. The training follows a progression. The idea is that you should first develop self-compassion—notice how you yearn for happiness and well-being and observe the mental states that hold you back from achieving that happiness. Next, you should cultivate equanimity and impartiality (i.e., see all humans as yearning for and deserving that same happiness) through an appreciation and gratitude for the kindnesses of others. The next step is to foster affection and empathy, which might then give rise to compassion—the wish to see others free from suffering. The average effect of compassion training on measures of compassion is 0.38 *SD*, indicating that the average compassion-trained meditator is more compassionate than 65% of nonmeditators.

Note that the effect sizes for the two studies that used the dictator game (in its first variation, the one where Player C could redistribute some—or all—of the money to the dictator's victim) are quite a bit higher than those for the studies using questionnaires (0.68 *SD* vs. 0.31 *SD*). The reason for this might be that compassion is easier to fake on paper than in real life. That is, for folks not trained in compassion, talk is cheap (and so they can afford to do well on a survey), but when actual money is involved (as in the game), they may back out a little. This has brought researchers like Tania Singer, who leads the ReSource Project,[60] to adopt measures that have even more at stake, such as actual donations to charity, to gauge the effects of empathy and compassion training. This project is still ongoing, and the first results are only now starting to come out. Here I highlight one thought-provoking finding from this project.[61] This study used the redistribute-and-punish variant of the dictator game, including a condition in which the participants themselves were shorted by the dictator. In that case, nonmeditators were more likely to retaliate than meditators, perhaps suggesting that nonmeditators took the slight a little more personally. This was confirmed by the finding that nonmeditators became angrier when they were victimized than the meditators did. But meditators were more likely to put their money where their heart was: When Player B was the victim, both groups were equally likely to punish the dictator (remember that doing so does not cost players any money; it's just not handed to the dictator), but meditators were more likely to recompense the victim than nonmeditators (this behavior, of course, costs participants money, because they give "theirs" away).

Effects of Mindfulness on Well-Being: A Summary

Taken together, the findings on meditation and well-being make an impressive list. Figure 3 provides a summary. In the graph, the length of the bars indicates the size of the effect. For each type of effect there are two bars: one (light gray) shows the effect averaged over all studies, and the other (darker gray) shows the effect only for those studies that were interventions (as opposed to studies that looked at differences between long-term meditators and novices). The error bars (the whiskers) indicate the 95% confidence interval. This interval tells us where the "true" effect lies with 95% certainty, given the mean effect, the variability in that effect (note, e.g., that the effect sizes for depression were more alike than those for state anxiety, and state anxiety thus has wider whiskers), and the number of studies involved (e.g., empathy was measured in only two studies, and so it has much wider whiskers than self-perceived stress, which was assessed in a large number of studies). The dashed line in the graph is the benchmark I described in Chapter 1: It represents the average effect of all educational, psychological, and behavioral interventions as calculated in a meta-meta-analysis of no less than 156 meta-analyses.[62]

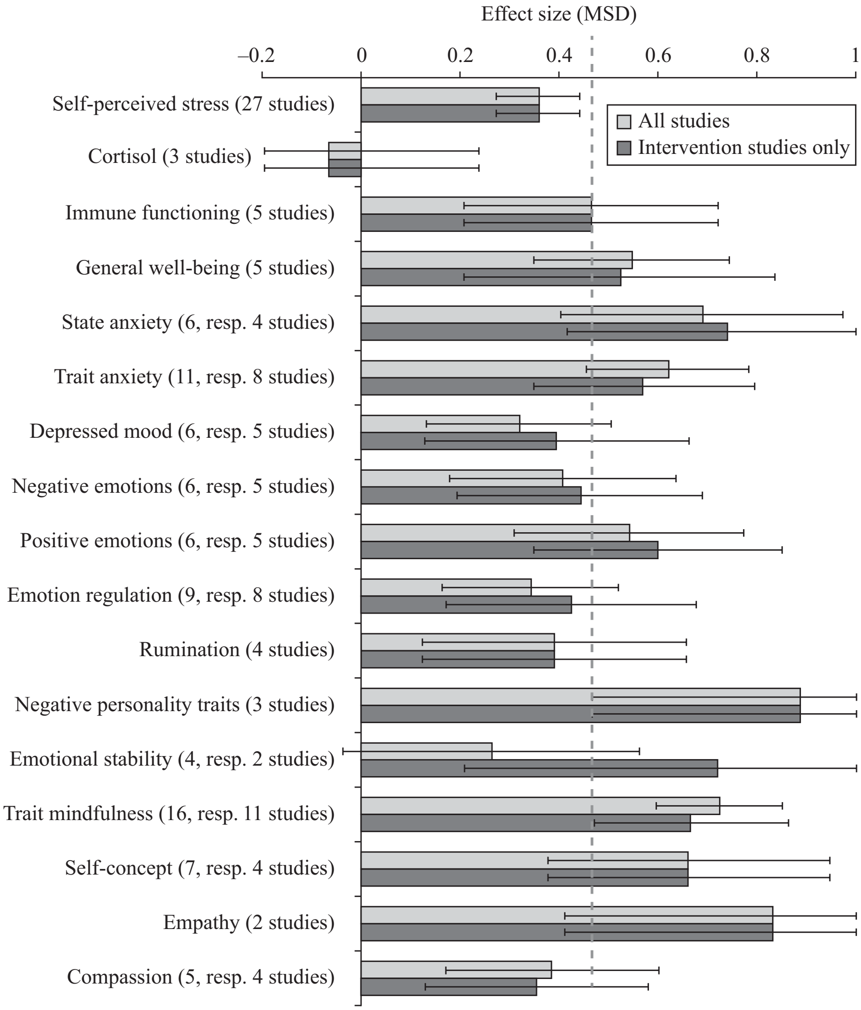

FIGURE 3 *The effects of mindfulness meditation on psychological well-being. The whiskers embrace the 95% confidence interval. The dashed line is the average effect size for 156 different types of psychological, educational, and behavioral interventions (Lipsey & Wilson, 1993).*

Looking at this summary graph, one fair conclusion is that a lot of good things seem to be happening to those who meditate (actually, these happen to the average meditator, and that is important to note too—there's no guarantee that every meditator will experience each [or even any] of those effects). Most of the whiskers in the graph straddle the dashed line, indicating that the size of the effects of mindfulness meditation are on par with what we would expect from a typical educational, psychological, or behavioral intervention. The effects on cortisol and self-perceived stress are smaller than expected;

those on trait mindfulness are larger. If the whiskers cross the zero line, the effect is not significantly different from zero; that is, we cannot say with certainty that mindfulness works in this case—this is only true for the effects on cortisol and emotional stability.

One conclusion is that mindfulness meditation is clearly not something that lifts you out of the realm of the ordinary to the *summum* of well-being, but it does help you along in life, just like any other good behavioral intervention worth its salt.

What strikes me most is that the palette of effects is so broad: Mindfulness seems to have a positive impact on just about any psychological variable we (as a field) have looked at—it makes you less stressful, boosts your immune function, makes you less anxious and less depressed, dampens your negative emotions, amplifies your positive emotions, helps regulate your emotions, makes you less ruminative, takes the edges off negative personality traits, makes you more mindful, strengthens your self-concept, and makes you more empathic and compassionate. (Plus it helps with attention too.) Mindfulness meditation is thus a broad-spectrum corrective to the psychological ailments of daily life.

The list is all the more impressive given that most of the studies included in these analyses are intervention studies that are relatively short—recall that the average duration was just over seven weeks. That is also the reason I highlighted just the intervention studies in the graph (in the dark gray bars). For most aspects of well-being, there isn't much difference between the effects from all available studies and those from only the intervention studies, suggesting that meditation's beneficial effects are already in full swing after a mere two months or so. Do note that there are precious few nonintervention studies in this batch, so I feel squeamish drawing firm conclusions about what happens in long-term meditators. Some of the effects we have seen—for instance that meditation helps with relationship stress but that the effect of a single meditation session lasts only for a few days—suggests that the effects of meditation may develop rather quickly but are relatively short-lived in the sense that they need a continuous boost from continued meditation. This reminds me of the effects of exercise on physical fitness: You can build up fitness relatively quickly, but you need to keep going at it or you risk losing the benefits.

One important limitation of these findings is that most of the studies (48 out of 57) used a passive rather than an active control group. This is a fair comparison if we want to see how the mindful meditating life compares to life as usual. (This is, I suspect, what most of us who meditate or are thinking of taking up meditation are interested in: What will this *add* to my life?) It isn't such a fair comparison if we want to see what mindfulness can do over and beyond another similar program, say, relaxation training. (This is the question the critical consumer should be concerned with: Should I take up meditation or yoga? Or go for a weekly massage?[63])

When we look at the effects compared to active groups study by study, the picture becomes less rosy. A good example is the study by Shamini Jain and colleagues.[64] Jain et al. found that both meditation training and relaxation training did better than passive treatment in decreasing stress and increasing positive mood. Meditation and relaxation had similar effects on distress, but meditation had a bigger impact on positive mood states. This study, then, teaches us that some of the effects of mindfulness (viz., on stress) might be due to the relaxation component inherent in meditation, and others (viz., on mood) are not. This is not an indictment of mindfulness meditation; I am only saying here that its effects aren't necessarily all due to meditation and/or mindfulness per se.

Likewise, Irving Kirsch and David Henry[65] found that meditation, relaxation, and a specific behavioral therapy technique (systematic desensitization) all reduced public-speaking anxiety in students to the same degree compared to a passive control group. They also found that the effects were larger for those students who believed that the treatment (whatever it was) would work. This then suggests that part of the effects of mindfulness on anxiety might be a placebo response—believing that mindfulness will work becomes a self-fulfilling prophecy.

In sum, we need more studies that include active control groups to help us figure out what the active ingredients of mindfulness meditation are. Given that these ingredients might differ by the type of effect we are looking at, studies of this kind would be especially helpful for people who want to take up meditation for a particular reason. If you want to reduce stress, relaxation therapy works just as well; if you want to improve mood, mindfulness generally does better. It would at least give beginning mindfulness practitioners a possible alternative if they find that meditation, or a particular type of meditation, is not something they easily relate to.

Another limitation of these findings is that most of these studies—and I apologize for singing the same refrain yet one more time—use very small numbers of participants, ranging from 8 to 140 in the meditator groups, with a mean of only 27 people per study. That makes it very risky to attach any form of firm conclusion to any given study. Meta-analysis helps, because the aggregation of the data should smooth out some sources of error, but a few large clinical trials (preferably organized across different research centers) would be extremely valuable here.

Do Your Homework: Adherence Matters

In previous chapters, I have looked at dose–response relationships. Most of the interventions I review here were relatively short, and so there is little to investigate in terms of dose–response relationships. Endre Visted and colleagues[66] found in a meta-analysis that programs that included a half-day retreat—which we can assume makes the program just a little more intensive—have larger effects on trait mindfulness than programs that do not.

Within programs, the variation in treatment dose is most likely to be found in actual time spent practicing rather than in-class time, which is presumably the same for all participants. I was able to collect five studies[67] that reported correlations between some form of adherence (either whether or not participants practiced on a given day or how many minutes they practiced) and trait mindfulness; the average correlation[68] was .18. I found seven studies[69] that reported correlations between adherence and stress; the average correlation[70] was .17. These are not very strong relationships, but they are positive: The more or longer you practice, the more benefits you are likely to reap. Two studies explicitly mentioned that the amount of informal, not formal, practice was important; the other five did not make the distinction. (My advice would be to neglect neither.)

One interesting finding in one of the studies[71] was that practicing at home was effective but trait mindfulness was a more powerful predictor of well-being (in this case, stress levels and rumination) than practice per se.

Why and How Does Meditation work? The Role of Trait Mindfulness

There are, of course, many reasons why meditation could have the effects that it has on all these aspects of well-being. The discussion here suggests that relatively pedestrian mechanisms, such as the relaxation component of meditation and/or meditators' expectations, do play a role.

Most psychologists in the field take a loftier view. Many mechanisms have been proposed, and there are even some (what psychologists call) "models"—connections between different mechanisms, as in "this leads to that." Basically, all of the models I have seen make intuitive sense.[72] They all have different emphases, but the list of proposed reasons why mindfulness meditation works generally contains three categories, as Vago and Silbersweig point out. One proposed mechanism is a *change in self-awareness*. This involves recognizing your automatic habits and your automatic patterns of reactivity, an increased awareness of momentary states of body and mind—what is typically meant by trait mindfulness. Another proposed mechanism is a *change in self-regulation.* This includes better regulation of emotions, heightened self-compassion, increased emotional and cognitive flexibility, and increased nonattachment and acceptance. A final proposed mechanism is *increased self-transcendence.* This implies increased decentering, a stronger awareness of interdependence between self and others, heightened compassion, and an emphasis on ethical practices.

Enthusiasm for model building has exceeded enthusiasm for model testing, alas. The only links that have been extensively researched are the ones involving trait mindfulness, starting from the assumption that it is the development of purposeful, nonjudging awareness that opens you up, destresses you, makes you less anxious, and so on. This makes sense: If you can approach the events that life throws at you—especially the ones you would typically classify as "bad"—with more acceptance and less judgment, they will have less of a negative impact. This will also allow you to go out into the world and explore with a bit more fearlessness. Ultimately, this might lead to letting go of the idea that you, the people around you, and your world in general need to be a certain way and stay that way forever.

How can we find out if that is really the case?

First, it makes sense that mindfulness might be the key mechanism, given what we know about trait mindfulness—it correlates with many aspects of well-being, as reviewed here. That is, people who are more naturally mindful tend to also enjoy higher levels of well-being. The idea, then, is that if trait mindfulness is associated with higher well-being, changing trait mindfulness for the better by taking up meditation would organically lead to higher well-being.

Let's review the correlations. I was able to find 20 studies[73] that provide correlations between trait mindfulness and at least one aspect of well-being in groups of nonmeditators. Trait mindfulness correlates[74] quite nicely with self-perceived stress (five studies, $r = 0.48$), general well-being (eight studies, $r = .44$), anxiety (two studies, $r = .34$), depressed mood (two studies, $r = .33$), negative emotions (four studies, $r = 0.43$), emotion regulation (three studies, $r = .22$), rumination (four studies, $r = .22$), and self-concept (four studies, all on self-compassion, $r = .46$). Correlations were small for positive emotions (four studies, $r = .13$) and empathy (three studies, $r = .10$). All of this suggests that people who are naturally more mindful are less stressed, feel better, are less anxious or depressed, regulate their emotions better, ruminate less, and have higher levels of self-compassion. A study by Jennifer Daubenmier and colleagues[75]—their participants were obese women—illustrates this nicely: They found that trait mindfulness worked as a buffer between perceived stress and the actual cortisol response. Women with low levels of mindfulness simply expressed their stress into the cortisol response—high stress, lots of cortisol. This was not the case for women with high levels of mindfulness, where perceived stress was decoupled from the cortisol response: Perhaps mindfulness—that tad of distance—kept them from being overwhelmed.

What about differences *within* a person? If your mindfulness fluctuates, what happens to your well-being? Wai Kai Hou and colleagues[76] tested 105 college students in Hong Kong before and after an intensive examination period. They found that changes in mindfulness from before to during to after the exam period were mirrored in changes in affect, anxiety symptoms, and the cortisol stress response—students who were more mindful suffered less. This finding suggests that natural fluctuations in mindfulness (if we consider exams a natural occurrence) are mirrored in stress and mood.

If mindfulness and well-being fluctuate together in the real world, we might expect to see the same in mindfulness training. If it is true that trait mindfulness is the driving factor in changes in well-being after a mindfulness program, then we would expect that, over the course of the program, *changes* in trait mindfulness would give rise to changes in well-being. In a research study, this would show up as a positive correlation between changes in mindfulness and changes in well-being: People whose trait mindfulness increases more should show higher levels of well-being. This appears to be the case. I found 13 studies[77] that reported correlations between changes in mindfulness over the course of a mindfulness intervention and changes in one or more aspects of well-being over the same time period.[78] The results are quite supportive of the idea of a coupling between mindfulness and well-being: Changes in mindfulness correlate[79] with changes in self-perceived stress (six studies; $r = .54$[80]), anxiety (two studies, $r = .51$), depressed mood (two studies; $r = .62$), positive affect (three studies; $r = .26$), negative affect (two studies; $r = .14$), rumination (one study; $r = .36$), and general well-being (two studies; $r = .35$).

These results are compatible with the view that changes in trait mindfulness are the basis for further changes in well-being. If we hadn't found these correlations, that hypothesis would be in trouble. But this finding doesn't mean that the hypothesis is necessarily correct: The relationship could be the other way around (maybe higher well-being leads to sharpened mindfulness), or the relationship could be mutually reinforcing, or something else could cause both changes in well-being and changes in mindfulness.

To check whether mindfulness really is the forerunner of changes in well-being, we need a more fine-grained analysis. Recall that these effects largely develop within two months or sooner, and so the usual two-shot approach—testing once before an MBSR-type program and once after—cannot tell us much in terms of what is the driving force. We need studies with more data points.

I was able to find three such studies. The first of these, by Jon Vøllestad and colleagues[81] doesn't teach us much. By the end of training, changes in mindfulness indeed explained most of the changes occurring in anxiety and rumination. However, the researchers didn't find any evidence for a change in mindfulness by the midpoint of training. Of course, it is still possible that mindfulness could be the forerunner but it just takes more than four weeks for mindfulness changes to become visible, after which changes in well-being follow rapidly.

The second study, by Ruth Baer and colleagues,[82] with eight measurement points, once for every week of an MBSR program, did find significant changes in trait mindfulness by the end of the second week; changes in perceived stress appeared a little later, by week 4. In this study, mindfulness continued to increase over the whole course of the program, so one possible explanation for the delay could be that mindfulness needs to reach a certain level before it spills over into other aspects of daily life. Comparing change scores (survey results after training minus survey results before) showed that changes in mindfulness and changes in perceived stress were correlated, as they should be. Also of note here is that the appearance of changes in mindfulness was related to whether or not participants practiced according to the instructions: Those who did practice by the book achieved larger changes in mindfulness over the course of the first three weeks. All of this suggests a simple cascade: Practicing diligently (or at least correctly) leads to an increase in trait mindfulness that becomes statistically visible after a few weeks, followed a few weeks later by a decrease in perceived stress.

Finally, Evelien Snippe and colleagues[83] assessed mindfulness and positive and negative mood on a daily basis during an MBSR program. They found that day-to-day fluctuations in mindfulness predicted day-to-day fluctuations in mood (more specifically: Higher levels of mindfulness on a given day were followed by a happier mood on the next day) but not the other way around. This is very strong evidence for the role of mindfulness as the forerunner of well-being (or at least of mood), and it is a faster-churning cascade than the one Baer et al. found. Snippe et al.'s result also implies that there isn't much of a feedback loop—while it is the case that mindfulness puts you in a better mood, better mood does not lead to further increases in mindfulness. As in the Baer et al. study, home practice was important: Doing at least one mindfulness exercise during the day was followed by higher levels of trait mindfulness in the evening.

One additional interesting finding in this study was that people differed in the strength of the coupling; some people had stronger mindfulness–mood relationships than others. The cause of these differences is not clear. The researchers looked, and it wasn't gender, age, level of education, the amount of practice at home, or levels of mindfulness or mood at the beginning of the program.

Taken together, the results strongly speak for a model in which mindfulness practice leads to an increase in trait mindfulness, which then in turn leads to changes in well-being. We don't know much about the details of this cascade yet. Vøllestad et al. looked at anxiety and rumination, Baer et al. at stress, and Snippe et al. at mood. It is possible that the differences in the results of these studies are due to the outcome measure. It might be harder to change anxiety than to change stress levels, for instance, and harder to change stress levels than to improve mood. This would suggest a cascade within the cascade, where mindfulness first has an effect on mood, which in turn affects stress, which then might help with anxiety—we simply don't know. If we would want to know, we need a study using daily measurements with a wide battery of well-being measures.

I should add two caveats to this model.

First, it is possible that the cascade starts even earlier. That is certainly what the Buddhist tradition states: It considers changes in attention as the first and necessary forerunner to any kind of other psychological change. This model would then predict that the changes in self-awareness and self-regulation would themselves be consequences of attention training. I discussed a few of those connections in Chapter 3, where we saw that increases in well-being and mood might be side effects of the attention-related aspects of meditation on brain structure. Earlier in this chapter we saw that changes in attention and changes in mindfulness are at least connected (four studies, $r = .47$). These are correlations that we would need to see in order for the model to work, but they do not confirm that the model is true—for that, we would need to see the kind of cascade data I discussed in this section.

The second caveat is that there may be more than one route to boosting trait mindfulness. A recent meta-analysis by Endre Visted and colleagues[84] has shown that active control groups (including progressive muscle relaxation, antidepressant treatment, and psychotherapy) can produce changes in mindfulness that are just as large as those in mindfulness-trained groups (mindfulness training had an additional effect of a meager and nonsignificant 0.10 *SD*). So meditation or mindfulness training per se is not necessary to produce changes in trait mindfulness. It does remain to be seen whether these active control groups produce changes in well-being and whether those changes are correlated with changes in mindfulness.

Mindfulness in Special Populations: Schools, Prisons, and at Work

The studies I review in this chapter are (almost) all done on nonclinical samples of (typically younger) adults. Mindfulness programs have, of course, branched out considerably in the past few years.

One such branching out has been to **school** settings. A meta-analysis by Charlotte Zenner and colleagues[85] on 24 mindfulness interventions in schools looked for (and found) effects on cognition (attention, creativity, mind-wandering, and school grades; 0.80 *SD*), emotional problems (maladaptive emotion, cognition and behavior, anxiety, depression, test anxiety, rumination, emotion regulation difficulties, and somatic reactions; 0.19 *SD*), stress (stress and coping; 0.39 *SD*), and resilience (well-being, positive emotions, resiliency, social skills, self-concept, and self-esteem; 0.36 *SD*). One big problem with this data set is that, as the researchers note, there is rather strong evidence for a rather significant publication bias—there are a lot fewer low and negative-effect studies than you would expect, given the data.[86] Overall, there is some evidence that mindfulness works in schools and that it has its largest effect on cognition (mostly measures of attention) in these studies. Zenner et al. also found evidence for a dose–response relationship: The number of minutes of formal training within each program correlated very strongly with the size of the effect[87] (r = .72 for controlled studies).

Mindfulness has also been applied to **work** setting. For instance, Koichiro Shiba and colleagues[88] found, in a large sample of 1,470 individuals in Japan, including 418 meditators, that meditation was associated with higher levels of work engagement, better self-rated job performance, and higher levels of job satisfaction.[89]

Finally, there has been some work using mindfulness in **correctional** settings.[90] In a review of the available eight studies, Edo Shonin and colleagues[91] conclude that there are significant improvements on negative affect, substance use, anger and hostility, stress, self-esteem, and optimism.[92]

Mindfulness and Well-Being: A Few Conclusions

The quick summary of the findings from this chapter is that the practice of mindful meditation seems to be associated with a number of positive effects, with no negative effects noted. Mindful practice cascades into changes in trait mindfulness, which in turn lead to changes in other aspects of well-being. One of the more interesting conclusions is that the beneficial effects of meditation and mindfulness are not acquired rights—something you didn't possess before the training and afterward are yours to keep. Quite a few studies—for instance, Carson et al.'s work on couples, and Baer and Snippe's study using frequent measurements—show that some of the psychological effects of mindfulness practice are restricted in time, lasting a few days or so at most. The advice here would simply be to practice often.

One common thread through many of the studies I discuss within this chapter is the theme of a more open-minded, nonjudgmental stance to what is happening inside the body and in the outside world—a lowering of reactivity. We saw this in Lin et al.'s musicians, Carson et al.'s couples, and McCall et al.'s compassion-trained benevolent dictators. We also saw in the previous chapter that attention takes on this more open character.

There are still many open questions. One concerns the actual active ingredients of mindfulness training. We need more studies that contrast the effects of mindfulness programs with specific active control groups to find out what those are. Right now, it appears that relaxation and placebo effects are at least part of the response to meditation training.

Another open question is whether everyone benefits equally from mindfulness training, or even whether everybody benefits. There are a few studies that tackle this question, but more would be welcome. In a sample of college students, Michael de Vibe and colleagues[93] found larger benefits on stress reduction and general well-being in individuals who were more neurotic (i.e., less emotionally stable); participants who scored higher on conscientiousness experienced less study stress after the training. This suggests that different types of people might score different effects from mindfulness training. Jennifer Mascaro and colleagues[94] tested people's brains before they started compassion training. They found that people who activated the empathy regions of the brain[95] more strongly when they saw someone else experience pain were more engaged with the training. This then suggests that prior sensibilities might play a role in how well you connect with a particular practice. Clearly, we are only just starting to explore what effects or what type of engagement we could expect from what type of person.

Likewise, it would be good to know for whom mindfulness training may be most effective. Snippe et al. found that people differ in the extent to which changes in mindfulness are coupled with changes in well-being; some people get more traction than others. Ideally, we would like to see strong coupling (when mindfulness goes up, so does well-being), but we don't know yet why certain people have a stronger mindfulness–well-being coupling than others, nor do we know what can be done about this.

{ 7 }

Mindfulness as Medicine

As I mentioned in Chapter 1, MBSR and its many offspring (with MBCT being perhaps the most successful) were originally started as *clinical* programs. MBSR was designed at what was then called the Stress Reduction Clinic at the University of Massachusetts Medical Center; MBCT was explicitly developed as a program to prevent relapse in previously depressed individuals—mindfulness and meditation as a form of therapy. The clinical work in this area has focused mostly on people suffering from depression (or the recently depressed who might be likely to relapse into depression) or various forms of anxiety disorders, as well as people suffering from chronic pain (as a primary ailment or as a secondary aspect of a medical condition, e.g., during cancer treatment) or chronic stress.

In the previous chapter, I discussed the primary methodology of clinical research: Randomized controlled clinical trials are the gold standard. How do studies on the therapeutic effects of mindfulness measure up against that standard?

Not so well, it turns out. Many of the published meta-analyses—and there are a few[1]—document the process by which studies were selected. This includes detailing the reason why particular studies, once retrieved from the library, were ultimately excluded from the analysis. The arguably most stringent meta-analysis in the field is the one by Madhav Goyal and colleagues[2]: It focuses only on randomized controlled trials with active controls. (Goyal et al.'s focus was on meditation in general, and so the paper did include not only mindfulness trainings; mantra practice was included as well.) The researchers initially retrieved an incredible 18,753 papers; they ended up with no more than 47 in the final analysis—discarding about 99.75% of the original set. There were a number of reasons for rejection. Some were trivial: Studies that simply did not fit, like work focusing on children or adolescents, or research done on healthy volunteers, or studies that did not contain the kind of clinical measures Goyal et al. were interested in. Noteworthy was the large number of papers that did not contain original data, that is, review papers or position papers—a full 45%.[3] Of the papers that contained original research, 20% did not include a control group and 26% did not randomize participants. Thus about half of the empirical research falls well short of the accepted standard in the field of clinical research.

Meta-Analyses of the Effects of Mindfulness in Clinical Populations

Let's delve into a few of those meta-analyses, starting with the most comprehensive analysis, the one by Goyal and colleagues. Goyal et al. examined changes in **mental health** in clinical populations (specifically, changes in depression, anxiety, stress and distress, mood and affect, substance use, eating and sleeping patterns, pain, and body weight). "Clinical population" was defined broadly here: About a third of the studies targeted individuals suffering from psychological distress (viz., depression, anxiety, stress, or substance abuse), while the rest suffered from medical problems that often lead to psychological distress (viz., asthma, breast cancer, cardiovascular disease, chronic pain, diabetes, organ transplant, or tinnitus; typically each study tackled only one problem). As mentioned, Goyal et al. looked at interventions using either or both mindfulness and mantra meditation—my interest here, given the topic of this book, is in mindfulness interventions, so I report results on this type of meditation only.[4] Only randomized controlled trials with active controls were included, yielding a small set of studies: 38 articles that focused on mindfulness interventions. The average sample size was 74 people per study for a total of 2,895 participants. Goyal et al. analyzed the data separately for nonspecific active control and specific active control. Recall from the previous chapter that "nonspecific active control" refers to a control condition that is not a known form of therapy (an example would be an educational intervention); "specific active control" is a known form of therapy (e.g., relaxation therapy or psychotherapy). Comparing the effects of mindfulness to the effects of nonspecific control conditions tells us whether mindfulness has an effect over and beyond placebo. Comparing the effects of mindfulness to the effects of specific control conditions tells us whether mindfulness has an effect that is larger (or smaller) than the effect of treatment-as-usual.

The first set of results concerns the comparison of mindfulness programs with **nonspecific controls**. In general (but not always), the effects of mindfulness training exceed those of placebo treatment: For anxiety, the effect size was 0.38 *SD* (7 studies); for depression, 0.30 *SD* (8 studies); for stress, 0.04 SD (7 studies, this effect was not significantly different from zero); for negative emotions, 0.33 *SD* (11 studies); for measures of positive emotions (e.g., well-being, positive mood), 0.28 *SD* (4 studies, not significant); for measures of quality of life as it related to health, 0.28 *SD* (3 studies, the effect was not significant);

for measures of sleep quantity or quality, 0.14 *SD* (4 studies, not significant); and for pain, 0.33 *SD* (4 studies). Thus mindfulness clearly has a real effect in clinical populations, over and beyond its possible effect as a placebo, on quite a few outcomes that do matter—depression, anxiety, negative emotions, and pain. There are also several important outcomes that do not show significant effects: sleep, stress, mood, and quality of life. The effect sizes are generally a little smaller than the effect sizes we observed in nonclinical studies in the previous chapter (around 0.30 *SD*, implying that mindfulness-trained people do better than 62% of nontreated individuals). Particularly nice to note is that the effect size of mindfulness on depression (0.30 *SD*) is larger than the typical effect of drug treatment: The effect of antidepressants for depressed patients with mild to moderate symptoms compared to nonspecific treatment is 0.11 *SD*; for those with severe depression, it is 0.17 *SD*.[5] For anxiety, however, both drug treatment (placebo-controlled effect size of 0.80 *SD* for panic disorder and 0.90 *SD* for generalized anxiety disorder) and standard psychological treatment (placebo-controlled effect size of 0.73 *SD* after cognitive behavioral therapy) seriously outperform mindfulness treatments (0.38 *SD*).

How does mindfulness compare to **specific active control** treatments? For anxiety, the effect size was –0.07 *SD* (10 studies; a negative effect size means that the control group performed better, but do remember that the effect is not significant, meaning that it is for statistical purposes equal to zero); for depression, 0.11 *SD* (11 studies); for measures of stress, 0.03 *SD* (6 studies); for positive affect, –0.04 *SD* (4 studies); for measures of quality of life, 0.05 *SD* (5 studies); for sleep, –0.14 SD (2 studies); and for pain, –0.06 *SD* (4 studies). The only significant effect (and it was a small effect) was for depression.

This result means that, for almost all mental health outcomes (depression is the sole exception), mindfulness does not work any better (or any worse) than treatment as usual. This is bad news for those who were hoping that mindfulness would be a therapeutic magic bullet, curing a wide variety of psychological ailments with much more ease than standard treatments do. It does not.

The result does mean that mindfulness training is a viable alternative to traditional therapies—it is just as effective as treatment-as-usual. This is an important finding because some of the treatments-as-usual can have unpleasant side effects. For instance, the most commonly prescribed class of antidepressants (selective serotonin reuptake inhibitors such as Zoloft, Praxil, or Prozac, sometimes also prescribed for anxiety disorders) can lead to nausea, restlessness, dizziness, reduced sexual desire, difficulty reaching orgasm, insomnia, and/or weight gain or weight loss. Xanax, commonly prescribed for anxiety disorder, has side effects such as drowsiness, dizziness, insomnia, memory problems, poor balance or coordination, slurred speech, and/or loss of concentration.[6] Goyal et al. are keen to point out (and other meta-analyses of clinical trials confirm this) that not a single instance of negative side effects has been noted in any of these mindfulness studies.[7] So mindfulness is a more than acceptable alternative for those who do not tolerate these drugs very well and/or for those who prefer a more contemplative approach over more traditional therapeutic tactics. This observation works both ways, of course: There is no reason whatsoever to prefer mindfulness programs over other forms of treatment. Thus people who find themselves unhappy in a mindfulness program should also feel free to step out and try something else. (Meditating just because you've heard it is good for you, without enjoying it, does not seem like a very sustainable practice anyway.)

Mindfulness can also be used as a **complementary intervention**, that is, as an intervention that is added to treatment-as-usual. In a review paper on this topic, Chiesa and Serretti[8] note that the evidence is scarce but somewhat encouraging. In the four studies that compared the combination of MBCT and treatment-as-usual with treatment-as-usual on its own, relapse rates for depression were half as large for the combined treatment compared to treatment-as-usual on its own. In the two studies that looked at the severity of depressive symptoms, however, combined treatment was not superior to treatment-as-usual.

Finally, a few meta-analyses (each looking at a small number of studies) have focused more specifically on mindfulness as a **treatment for the negative psychological effects of medical problems**. One of these[9] looked at the effects of MBSR in **cancer patients** (most of these concerned women with Stage II breast cancer). Over three randomized controlled trials studies, the mean effect on mental health (anxiety, depression, and stress) was 0.35 *SD*; for physical health (immunity levels, dietary fat, hormonal indices, as well as self-reported health), it was 0.17 *SD*, which was not statistically significant.

Another meta-analysis[10] focused on **chronic pain patients** (including fibromyalgia and rheumatoid arthritis) and included both MBSR and ACT interventions (with MBSR comprising about 80% of all studies). Averaging across all controlled studies included in the analysis, the interventions had statistically significant effects on pain (0.37 *SD*; 10 studies), depression (0.32 *SD*; 9 studies), anxiety (0.40 *SD*; 5 studies), physical well-being (0.35 *SD*; 6 studies), and quality of life (0.41 *SD*; 6 studies).

A third analysis[11] examined the effects of mindfulness interventions on **psychosis**. Psychosis is a mental condition in which a person loses touch with reality. Symptoms include delusions (false beliefs that are held with strong conviction, even in the face of evidence to the contrary) and hallucinations (sensations that seem very real but have no basis in reality; typically hearing voices or seeing things that aren't there); often the symptoms also include disorganized speech and disorganized behavior or a state of immobility. The meta-analysis found evidence for effects on the so-called negative symptoms of psychosis (i.e., the disruptions to normal emotions and behaviors, things like flat affect, lack of pleasure, difficulty interacting with other people; 0.56

SD; three studies). Mindfulness-trained participants were also less likely to be rehospitalized (0.60 *SD*; two studies). There were, however, no effects on so-called positive symptoms (i.e., hallucinations, delusions, or thought disorders; 0.19 *SD*, not significant; four studies).

All of these meta-analyses show promising effects, but it bears repeating that they are based on a very small number of studies.

The Effects of Mindfulness on Targeted Symptoms

The Goyal et al. meta-analysis examined mental health outcomes regardless of the underlying mental or physical health issue. What is affected in such cases is not necessarily the target of the intervention. For instance, MBCT is a treatment that was explicitly designed to keep formerly depressed individuals from relapsing. Its target is thus relapse prevention; the most honest way to see if MBCT works would then be to look at relapse rates. It would be nice if other effects were present as well—say, a reduction in anxiety or an increase in well-being—but this would not be critical in assessing its success. Goyal et al.'s meta-analysis does not make that distinction; the risk is that the (hopefully large) effect on target measures is confounded with the (possibly smaller) effect on nontarget measures and thus potentially diluted.

Piet and Hougaard[12] found that the relapse rate after MBCT training in six randomized active controlled trials was 38% in MBCT participants versus 58% for control participants—a reduction in the risk of relapse by 34%. Importantly, MBCT was even a little more effective for participants who were at a higher risk for relapse: For participants with three or more prior episodes of depression, risk of relapse was reduced by 43% (36% for MBCT participants vs. 63% for controls). Moreover, MBCT was at least as effective as a maintenance dose of antidepressant medication in the two studies that examined this question. Clearly, MBCT does not reduce the relapse rate to zero—that would be a bit much to ask for anyway—but it performs better than standard treatment.

Khoury and colleagues[13] provide additional meta-analytic data that show that effects are larger on target measures. They did not restrict the analysis to controlled studies but focused on progress from before to after a mindfulness intervention. They found an effect size of 0.57 *SD* across all measures (72 studies) but somewhat larger gains for more targeted interventions: 0.66 *SD* for depression in studies targeting depression (6 studies) and 0.72 *SD* for anxiety in studies targeting anxiety (10 studies). For studies with passive control, the average after versus before effect was 0.53 *SD* (67 studies). Effects were identical for depression in studies targeting depression (eight studies; effect size = 0.53 *SD*), but were 1.00 *SD* for anxiety in studies targeting anxiety (four studies). The evidence is not spectacular, but there is at least a hint that people make the most progress on the type of outcome that is the explicit aim of the specific intervention.

Finally, Hofmann and colleagues[14] gathered studies on mental health; like Khoury et al., they focused on before to after progress. They found that mindfulness interventions were best at reducing anxiety in individuals with anxiety disorders (effect size = 0.97 *SD*; seven studies) and less effective in reducing anxiety in cancer patients (0.64 *SD*; eight studies) or people suffering from pain (0.44 *SD*; five studies); there was only a small, statistically not significant reduction in anxiety in depressed individuals (0.12 *SD*; one study). Mindfulness interventions worked well at reducing depression in depressed individuals (effect size = 0.95 *SD*; four studies) and did less well at reducing depression in anxious individuals (0.75 *SD*; six studies), individuals suffering from chronic pain (0.51 *SD*; six studies), or cancer patients (0.45 *SD*; seven studies). Thus progress is largest in the area of life where people are suffering most.

In sum, there is reason to be cautiously optimistic: Mindfulness-based therapy seems to have targeted effects. That is, mindfulness therapy aimed at reducing relapse reduces relapse (and more so than treatment-as-usual), people generally make the most progress on the type of mental health outcome that is the explicit target of the specific intervention, and mindfulness training is most effective at lightening the burden where it is felt the most.

Dose–Response Relationships

How long does a person need to be in mindfulness training for it to be effective?

In their meta-analysis, Khoury and colleagues found a small but significant effect of the **duration of treatment** (i.e., the number of contact hours between therapist and clients) on measures of psychological distress. For every hour increase in duration, the effect size went up by 0.01 *SD*. The MBSR standard of practice[15] is 34 contact hours; increasing that number to 44 would then increase the effect size by 0.10 *SD*. This suggests that, at least for MBSR and MBCT-style programs, some of the effective work is done in class. We don't know why—there is no research on this—but part of the effect may be due to "modeling," that is, teaching by example (from the point of view of the therapist) and learning by imitation (from the point of view of the participant). An indication that this may be the case comes from studies where the therapist herself had received mindfulness training—these studies had, on average, an effect that was 0.13 *SD* larger than studies where the therapist wasn't trained in mindfulness.[16]

One other meta-analysis[17] looked at the effect of the number of in-class contact hours within MBSR (30 studies); no effect was found. (The authors also, incidentally, found that the number of contact hours in these studies was much lower than the standard of 34: It varied between 6 and 28, with a mean of 19.) One possible explanation for the discrepancy is that the Khoury et al. meta-analysis may have had a wider range of durations (the paper doesn't tell us), implying that durations longer than 28 hours are critical and/or that short programs are particularly ineffective. Another possibility is that some types of treatments may take longer to kick in than others, and if the longer treatment is more effective simply because it is a better treatment, this will show up in the Khoury et al. results as an effect of duration. I hate to use the cliché yet again, but—yes—more research is necessary.

Interestingly, in the Khoury et al. meta-analysis, the **number of hours practiced at home** did not predict treatment success. This study, however, used the number of hours prescribed by the program for the analysis—no doubt due to the absence of actual data on the amount of homework practice. People being people, it is unlikely that any participant followed his mindfulness coaches' prescription to the letter.

There is one review paper, by Lisa Christine Vettese and colleagues,[18] that directly addresses this question. They examined the effect of dosage by looking at the effect of home practice as reported by the participants themselves. Another difference is that they looked at this within individual studies. The Khoury et al. and Carmody and Baer studies looked at practice across studies—does Study A, with a shorter duration, yield a smaller effect than Study B, with a longer duration? That is a different question than the question of whether people who are enrolled in Study A (or Study B) and practice diligently do better than the slackers in Study A (or Study B). I would argue that the latter analysis makes more sense from a scientific standpoint because it keeps all other aspects constant. (It is likely that there are other differences between Study A and Study B than just duration.)

One interesting conclusion from Vettese et al.'s review was that very few studies have examined this question: Vettese et al. collected 98 applicable studies, but only 24 of those looked at the relationship between how well participants practiced at home and how that helped alleviate their psychological distress. Of those 24, 15 allowed for the calculation of amount of practice in the form of minutes per day—on average, participants practiced 28 minutes per day during the program, ranging from 5 minutes per day in one study to 58 minutes per day in another. (These numbers are testimony to the determination of the participants: half an hour of meditation and/or other mindfulness practices per day seems very respectable to me.) Five studies also reported practice at follow-up (with follow-up times ranging from two months to four years), which varied from 5 minutes per day less than once per week to 18.7 minutes per day every day. Of the initial 24 studies, 13 (just over half) showed at least moderate support for a relationship between the amount of home practice and psychological outcome. Vettese et al. did not crunch the numbers, but I calculated an average correlation over all 24 studies of $r = .15$.[19] This correlation is very close to the corresponding correlation in nonclinical samples we saw in the previous chapter ($r = .18$ for trait mindfulness and .17 for stress)—a small but positive association suggesting that how much you practice has a modest influence on the effect you can expect to score.

Why and How Does Meditation Work? The Role of Trait Mindfulness and Rumination

Mindfulness training thus appears to be an effective form of therapy for mental health issues—it works better than placebo, its effectiveness is on par with that of standard treatment, and it works better for preventing relapse after depression than treatment-as-usual does. It also has positive effects on mental health for people afflicted with a diverse array of medical conditions.

In the previous chapter, we saw that many mechanisms have been proposed for effects on well-being but only trait mindfulness has gained some empirical traction in nonclinical samples. It is probably fair to say that there has been more attention to the "why" question in clinical research. In their review paper, Jenny Gu and colleagues identified 20 studies on mechanisms; Anne Maj van der Velden and colleagues collected 23.[20] These studies also (and for the present purposes also, alas) cover a wide variety of these mechanisms: Only two mechanisms have been investigated in more than three studies (if we take three studies as the absolute minimum to conduct a meta-analysis).

The first of these oft-researched mechanisms is our old friend **trait mindfulness**—the self-reported ability to be present in and open to the present experience. Gu et al. collected 12 studies that looked at mindfulness and allowed for the computation of correlations. Seven of these examined levels of depression as the main psychological outcome; two focused on stress, two more on anxiety, and one on negative affect. In these studies, the effect of the mindfulness intervention on trait mindfulness was, on average, 0.72 *SD*; changes in mindfulness were correlated with changes in psychological outcome ($r = .36$). On average, changes in mindfulness after the intervention explained 61% of the changes in the mental health outcome. Another meta-analysis[21] found this effect also between studies; that is, studies that resulted in stronger effects on trait mindfulness also showed more positive effects on mental health. Technically, we cannot claim that changes in mindfulness lead to changes in psychological outcomes—these are correlations, not a cascade of changes over time. I cannot think of a good reason, however, to assume that the cascade we saw in nonclinical studies (mindfulness practice leads to higher levels of trait mindfulness, which leads to heightened well-being) wouldn't also be present in these clinical groups.

The second mechanism is what Gu et al. labels "**repetitive negative thinking**"—this includes both **rumination** and **worry**, which fall under the self-regulation category in Vago and Silbersweig's categorization of effects (as we saw in the previous chapter). Recall from the previous chapter that rumination and worry tend to be particularly active in people who struggle with depression. Gu et al. found that the stilling of repetitive negative thinking explains a good amount of the changes in psychological outcome after a mindfulness intervention. They compiled six studies: three on depression and one each on stress, anxiety, and global symptoms of psychopathology. The effect of the mindfulness intervention on negative repetitive thinking in these studies was 0.65 *SD*; decreases in negative repetitive thinking were correlated with positive psychological outcomes ($r = .33$). On average, changes in repetitive negative thinking after the intervention explained 44% of the changes in the psychological outcome. If we assume a cascade (mindfulness practice causes you to ruminate less, which eases your symptoms), this means that a good portion of the effectiveness of mindfulness interventions is due to lowered levels of worry or rumination. Note that the positive changes in negative thinking after mindfulness interventions are important in their own right: For many people who have them, such persistent worries and seemingly unstoppable negative thought spirals are in themselves rather distressing. Finding some relief from their relentless onslaught is a welcome change.

How Long Do Intervention Effects Last?

Trait mindfulness and the ability to regulate thought and emotion (or at least not to lose oneself in rumination and worry) are useful skills to have, techniques that you can apply throughout life. Skill learning is wonderful, because you might hope that once the tool is in the toolbox, it is always at hand, helping you fight off further mental onslaughts. From this point of view, mindfulness training should be expected to have long-term effects.

There are two meta-analyses on long-term(ish) effects of mindfulness training on mental health. The first, by Stefan Hofmann and colleagues,[22] gathered 19 studies and looked at outcomes at the final follow-up compared to before the intervention. The mean follow-up length was 27 weeks after the end of training. The effect for anxiety (17 studies) was 0.60 *SD* (compared to 0.83 *SD* right after training); for depression (18 studies), the effect size was also 0.60 *SD* (compared to 0.50 *SD* right after training), suggesting, first, that effects are still measurable half a year after the training program and, second, that the effects do not differ much from those right at the end of training—they go down for anxiety (by 0.20 *SD*) and up a bit for depression (by 0.10 *SD*).

The second meta-analysis, by Bassam Khoury and colleagues[23] (the group of studies partially overlaps with Hofmann et al.'s) had an average follow-up length of 29 weeks. The effect size for the difference between the last follow-up and pretest (24 studies) was 0.57 *SD* (compared to 0.55 *SD* right after training). Mindfulness programs were very effective for the treatment of anxiety (0.91 *SD*, six studies, compared to 0.89 *SD* right after the intervention) and depression (0.75 *SD*, two studies, compared to 0.69 *SD* right after treatment). The conclusion is that, as with the Hofmann et al. analysis, mindfulness training leads to long-term effects that do not differ (in this case, at all) from the effects scored right after the training.

Khoury et al. also looked at comparisons between control treatment and mindfulness interventions at follow-up. This answers the question of whether or not mindfulness programs are more (or less) effective than standard forms of treatment: At follow-up, mindfulness treatment (17 studies) showed an effect size of 0.43 *SD* compared with passive control (effect size = 0.44 *SD* right after the training); the effect size was 0.24 *SD* compared with active control (30 studies; effect size = 0.34 *SD* right after the training). Seventeen studies compared mindfulness training with other psychological treatments. Mindfulness did better than supportive therapy[24] (effect size = 0.34 *SD*, three studies), but its effects were not different from those of relaxation (five studies), psycho-education (three studies), and traditional cognitive or behavioral therapy (six studies). The conclusion here is that, as was the case with effects measured right after the treatment, the effects of mindfulness practice are similar to the effects of other kinds of therapy; the exception is that mindfulness does better than supportive therapy.

Bottom line: The effects of mindfulness training in clinical populations are quite stable over time, at least for half a year or so.

Is Meditation Safe? Side Effects and Adverse Effects

You might wonder if meditation and mindfulness interventions are safe.

The website of the National Center for Complementary and Integrative Health (NCCIH, a subdivision of the National Institutes of Health)[25] states, perhaps a bit mysteriously: "Meditation is considered to be safe for healthy people. There have been rare reports that meditation could cause or worsen symptoms in people who have certain psychiatric problems, but this question has not been fully researched."

While the last part of the final sentence is undeniably true—the question of negative side effects hasn't been fully researched—the former part may be a bit puzzling. As we saw earlier in this chapter, the large-scale meta-analysis by

Goyal and colleagues—which concentrated on clinical samples—uncovered not a single case of harm.[26] Their database included 41 clinical trials; nine of these explicitly reported on the question of harm. One of these nine looked specifically for toxicities to hematologic, renal, and liver markers and found none; seven others explicitly reported that they found no harmful events; one did not comment on harm. Thus the NCCIH statement of caution may be a bit overcautious—so far, no clinical trial has reported that new symptoms were caused by, or existing symptoms worsened as a consequence of, mindfulness training. Your local MBSR or MBCT program is likely beneficial and unlikely to cause you harm. (Nothing can ever be fully guaranteed, of course.)

The NCCIH statement, however, covers more than mindfulness training—it is a statement about meditation in general. There are indeed a few papers that suggest that meditation can lead to negative side effects.[27] These include case studies of increased negativity (increased anxiety, unnecessary critical judgment), disorientation (being confused about who you are, "loss of self," spacing out), addiction to meditation (yes, it can happen), and interpersonal problems (such as unwarranted feelings of superiority, increased discomfort with friends), mania (an unexplained period of great excitement and euphoria), or psychotic episodes (losing touch with reality). This has brought some psychiatrists[28] to advocate for careful screening, without, alas, giving clear criteria as to what to screen for and how.

The most comprehensive study on this topic is an ongoing project by Willougby Britton and colleagues. They conducted interviews with nearly 40 people who were expressly recruited because they had experienced adverse effects of meditation (mostly done in a religious [Buddhist] context rather than as part of a therapeutic endeavor); many of them experienced impairments in daily functioning lasting between six months and more than 20 years. The results from this study haven't been published yet, but an article in *The Atlantic*,[29] a fascinating read, previews some of the findings, many centering around disorientation, often occurring during periods of intense practice such as retreats.

It isn't clear what proportion of meditators are at risk or what the risk factors are. Many of the former, it seems, are younger adults, in an age range where psychotic breakdowns occur more frequently than in any other age group, so the question is whether meditation is actually responsible for the episodes. The lack of strong data makes it hard to predict who is vulnerable or if there is a specific moment in meditation training when a person is most vulnerable. If you teach meditation or mindfulness, it would certainly be a good idea to keep an eye out for possible struggles your participants might be having; if you meditate and find yourself losing touch with yourself or with reality, you might want to discuss this with your teacher or your family doctor. A complicating factor is that some Buddhist traditions consider some of these adverse effects—especially disorientation—signs of progress. Thus there is some discussion about whether these adverse effects are really adverse and whether or not they should be treated.[30] Another complicating factor is that, according to one diary study[31] of a small group of MBSR participants, everyone is likely to struggle with distress related to the practice at some point or other during training. These temporary setbacks seem to resolve themselves as participants acquire a more observing, less reactive self.

Again, the results from clinical trials strongly suggest that these problems are unlikely to be widespread; so far, they are absent from the clinical applications of mindfulness.

Mindfulness as Medicine: Conclusions

The main conclusion from the research on clinical applications of mindfulness is that meditation can indeed be used as a form of medication—it has measurable effects on depression (both symptom severity and the risk of relapse), anxiety, mood, pain, and psychological problems that occur as reactions to medical issues, and it is generally safe. It is, however, clearly not a magic bullet or a "Buddha pill," as one recent book calls it.[32] A fair conclusion would be to say that it works, but not spectacularly so.

First, the effects of mindfulness programs aren't of very large magnitude: around 0.30 *SD* in comparisons with nonspecific controls, that is, after taking out the placebo effect. These effects are largely on par with the effects found on well-being in nonclinical groups. Note that the effects tend to be a bit larger for targeted interventions and that mindfulness has its largest effect on the aspect of life that the particular patient is struggling with most. For depression, mindfulness appears to work better than drug treatment; for anxiety, it does not.

Second, the effect decreases to zero when compared with specific active controls, implying that mindfulness programs do just as well as other known and respected treatments for depression, anxiety, and the like. On the plus side, this makes meditation a viable alternative to other therapies. Its usefulness is increased by the finding that—in clinical contexts—there seem to be no known adverse effects. Mindfulness can also be helpful for medical conditions—the psychological side effects of cancer, chronic pain, and some aspects of psychosis.

As far as we know now, the effects are due to two factors: an increase in trait mindfulness and a decrease in rumination and worry. There is some evidence for a dose–response relationship (more practice, better results), and the gains scored right after training are largely maintained over a period of half a year after training.

Many questions remain. First, we still know very little about the possible cascade of effects. Studies that look at multiple outcomes on a day-by-day basis and keep track of actual time practiced and its relationship to specific outcomes would be very helpful here.

Second, the stability of training effects over a half-year period is something that deserves more scrutiny. In the previous chapter, we found that at least some effects of mindfulness practice were limited in time—practicing leads to greater mindfulness, which leads to greater well-being over the course of, at most, a few days. Vetesse et al.'s meta-analysis suggests that once the actual training program is over, time spent in practice sloughs off, and so there must be something else at play to explain maintenance of practice effects. The likely ingredient is trait mindfulness—mindfulness as a skill that can and will be deployed whenever a threat arises, kicking in, for instance, when you find yourself ruminating or thinking anxious thoughts and thus stopping problems close to the root. It would be worthwhile to investigate this claim, maybe using a time-sampling approach (e.g., ping former participants on their phones a few times a day and record their experiences and their reactions to those experiences).

Third, we know very little about individual differences in effectiveness in these clinical programs. Is mindfulness training a good idea for everyone suffering from depression, anxiety, psychosis, or medical problems? If it is not, is there a way to find out before the patient begins an eight-week program or at least early in the program?

{ 8 }

Meditation and Mindfulness

FINAL WORDS

This has been a long book. It has certainly grown bigger than I originally envisioned it to be, and is probably longer than you wanted it to be (I hope you felt free to skip sections). At the same time, it is also still too short: I am sure that you—like me—have lots of questions that haven't been answered.

It seems appropriate to end this book by, first, giving a summary of the findings. The main question of course is whether mindfulness delivers. I'll answer that one first—the answer is "yes"—and then move on to the three questions from the end of Chapter 1. First, in this book, we looked at three levels of results: data from brain activation, data from brain morphology, and data from mind and behavior. Do these three levels show converging results? Second, do we have any idea why mindfulness works, and can we derive scientifically sound meditation practices from that knowledge? And finally, what is it that we do not know but probably should?

Mindfulness Delivers

Figure 4 puts together all the results of all the meta-analyses in this book that compared people trained in mindfulness and/or mindful meditation to control participants. The graph combines effects on attention and different aspects of stress and well-being as seen in healthy adults (from Chapters 5 and 6), as well as effects on different symptoms and aspects of well-being in clinical groups, compared both to placebo effects (i.e., comparison to nonspecific controls) and to treatment-as-usual (i.e., comparison to specific controls) (from Chapter 7). The whiskers embrace the 95% confidence interval for each effect; the bold line again represents the average effect of all educational, psychological, and behavioral interventions, as calculated in a meta-analysis of no less than 156 meta-analyses. We can benchmark the

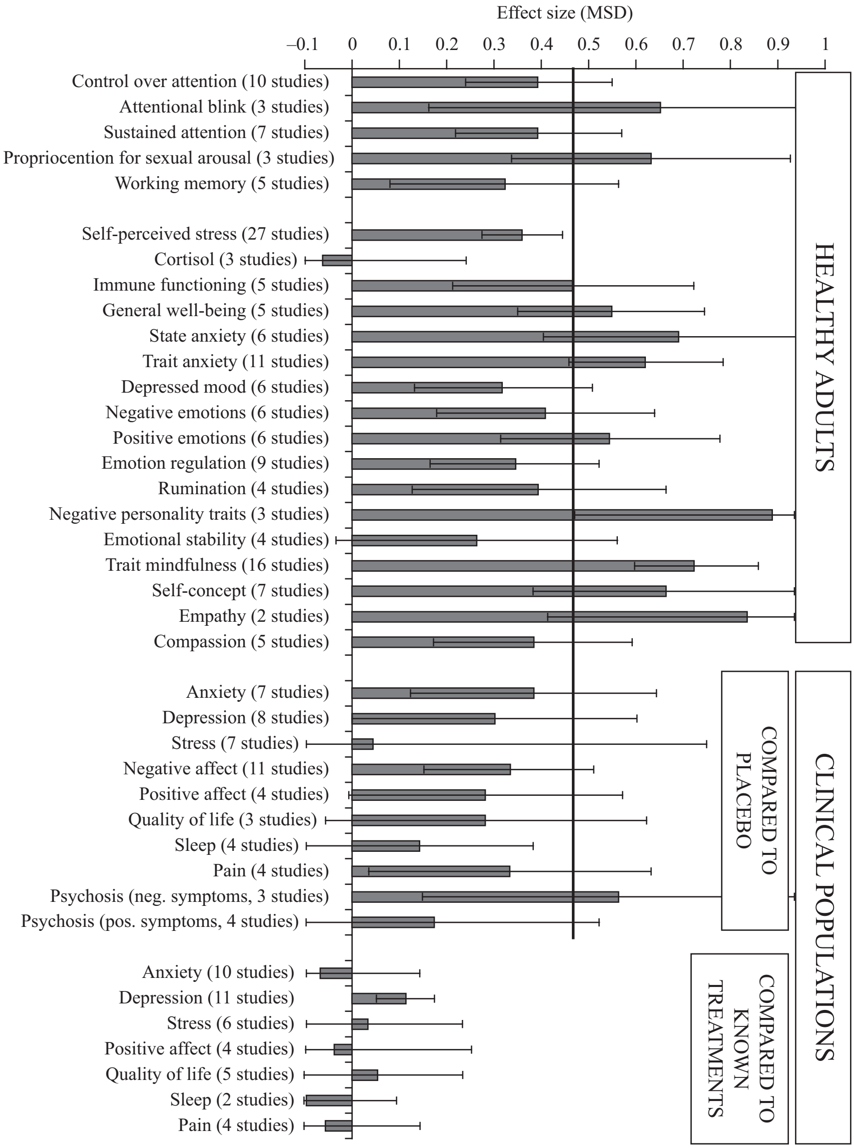

FIGURE 4. *Summary of the effects of mindfulness meditation in healthy and clinical populations. The whiskers embrace the 95% confidence interval. The bold line is the average effect size for 156 different types of psychological, educational, and behavioral interventions (Lipsey & Wilson, 1993).*

effects of mindfulness and/or mindful meditation against two standards. One is the zero line; this comparison answers the question whether meditating is better than just going on with your life. The other is the bold line, which answers the question how mindfulness and/or mindful meditation compare to what we can typically expect from interventions aimed at bettering our psychology.[1]

In the Preface, I mentioned Meng's dream—the hope that one day meditation and mindfulness would be as self-evident and nonremarkable as exercise is now. This dream can only come true if and when we—as a species—realize that mindfulness and meditation are good for us. I am very glad to report here that they are.

I summarize, first, the core findings concerning mindfulness and mindful meditation in healthy adults—mindfulness as a mental gym. Then I discuss mindfulness in a therapeutic context, or mindfulness as medicine.

MEDITATION AS A MENTAL GYM

To me, three discoveries stand out when looking at the effects of mindfulness training in healthy adults.

The first is statistical significance. In healthy adults, we have data on 22 different aspects of attention, stress, and well-being; 20 of those effects are larger than zero. The ones that are problematic are resting cortisol and emotional stability, but mindfulness/meditation has significant and beneficial effects on control over attention, attentional blink, sustained attention, proprioception for sexual arousal, working memory, perceived stress, immune functioning, general well-being, state anxiety, trait anxiety, depressed mood, negative emotions, positive emotions, emotion regulation, rumination, negative personality traits, trait mindfulness, self-concept, empathy, and compassion. (Yes, I realize you can read this from the graph, but isn't it very satisfying to just go through this list?) In sum, the effects of meditation are almost uniformly positive.

Second, mindfulness/meditation works just as well as standard psychological, educational, and behavioral interventions do, with a few exceptions. On the one hand, the beneficial effects on cortisol and self-perceived stress fall a bit short; on the other hand, the beneficial effects on negative personality traits and trait mindfulness are significantly larger than those of standard interventions. The average effect size over all 22 aspects is 0.49 *SD*, indicating that the average meditator is psychologically speaking better off than 68% of nonmeditators. This is a pretty strong result. No, meditation doesn't turn you into an off-the-charts super-being, but it does turn you into a more alert, smarter, happier, less anxious, more balanced, better feeling, more mindful, more emphatic, and more compassionate version of yourself—not a bad result at all.[2]

Third, the effects are amazingly broad. If you were disappointed to find that meditation works "only" as well as standard psychological interventions, consider that such interventions are usually targeted to a specific problem within a specific group. That is, marital counseling tries to make marriages work; Head Start hopes to improve toddlers' school readiness; relaxation therapy aims at making people feel less stressed; and so on. Essentially, typical psychological, behavioral, and educational interventions are one-trick ponies, as they should be: It's hard enough to change one thing in your life, let alone your whole life. Meditation, in contrast, has many effects in quite a number of domains in life—cognitive, emotional, and interpersonal.

This result offers an interesting parallel with physical exercise. Physical exercise also works on multiple aspects of physical well-being—it reduces your risk of cardiovascular disease, it strengthens your bones and muscles, it improves your mood, it might help you live longer, and it even makes you a tad smarter.[3] If your reason to start or continue a regimen of physical exercise would be that it has broad effects on a number of aspects of fitness that do matter, then you would have equal reason to take up or continue meditation—it positively affects many aspects of mind and heart that do matter. Meditation truly is a gym for your spirit. One exciting difference between physical exercise and meditation is that while exercise is good for *you*, meditation may also be good for those *around* you—you dull the edges of your negative traits, your positive mood might be contagious, and there is even some evidence that meditation makes you a better romantic partner.

In sum, meditation is a wonderful wellness tool, but it isn't necessarily better than anything else, if you are interested in just one outcome. (For instance, relaxation therapy is just as good at preventing or lessening the harms of stress as mindfulness is.) What sets mindfulness apart is its broad-spectrum efficacy—I can't think of any other intervention that has quite such a wide range of positive outcomes.

MINDFULNESS AS MEDICINE

In clinical samples, where mindfulness is applied as a form of therapy, we find a similar picture: Mindfulness/meditation has broad effects, comparable to those of standard practice. The effects tend to be somewhat smaller, though, and not always significant.

Compared to placebo treatment, meditation has a statistical significant effect on anxiety, depression, negative affect, pain, and the negative symptoms of psychosis but not on stress, positive affect, quality of life, sleep, or the positive symptoms of psychosis. We also find that meditation/mindfulness works just as well as standard treatment (the bold line in Figure 4) for all aspects, with the exception of sleep, where it is less effective. Note that the 95% confidence intervals for most outcomes are so wide that they embrace both the zero line and the bold line simply because there are few studies, and so the uncertainty (expressed in the width of the whiskers) is large. On average, the effect size is 0.28 *SD*, smaller than for healthy adults. The effect size indicates that the average mindfulness-trained patient is better off than 61% of nonmeditating, untreated patients. An important reminder is that, as we have seen, targeted interventions (e.g., MBCT, which targets depression relapse rates) have larger effects on the target measure than on nontarget measures. Likewise, effect sizes tend to be larger for the problem areas that participants are struggling with (e.g., depressed patients gain more on depression than on any other measure). We could thus rightly consider the effect sizes in the graph to be underestimates of the true target effect sizes.

In the comparison with treatment-as-usual, all confidence intervals contain zero. This indicates that mindfulness interventions have the same effect size as known treatments.

The conclusion here is that mindfulness/meditation does not propel you into the stratosphere of mental health, but it does have larger effects than placebo treatment and the same effects as treatment-as-usual, leaving people who are struggling with mental health issues with one more viable option. Mindfulness has the added advantages that it has broad effects that last for at least six months and that it is has no known negative side effects, at least in a clinical context (see Chapter 7).

The Time Course of Effects

One particularly thought-provoking set of findings concerns the unfolding of practice over time. In the previous section, I basically looked at the effects of meditating versus not meditating. But we can also make a more fine-grained distinction, namely between *local* effects—does the frequency or the number of minutes that you meditate per day matter?—and *cumulative* effects—does the total number of hours meditated over a lifetime make a difference? Note that these two types of effects aren't the same, but they are related: People who have meditated more over the course of a lifetime also tend to meditate more frequently and/or for longer periods than people who have accumulated fewer hours. (This is in part a simple math issue: The only way to accumulate more hours quickly is by sitting more and/or longer. In part, it is also the case that people often start sitting more frequently and/or for longer sessions as their practice progresses.)

One first finding (surprising to me) was that many of the effects of meditation are *not* the result of accumulated practice. Figure 3 (in Chapter 6) illustrates this nicely: The effects of meditation on many aspects of well-being are about the same whether we include all studies or only look at **intervention** studies (which contain, by definition, no long-term meditators). If the number of cumulative hours mattered, effect sizes would go down drastically when only intervention studies are considered; this is the case for exactly zero of the 16 aspects studied.[4] Thus the effects of meditation on self-perceived stress, immune functioning, general well-being, state anxiety, trait anxiety, depressed mood, negative emotions, positive emotions, emotion regulation, rumination, negative personality traits, emotional stability, trait mindfulness, self-concept, empathy, and compassion are already in full swing after about two months of training.[5]

Or maybe I shouldn't be surprised. The analogy with exercise might work here too: Your level of fitness isn't so much due to how much you've exercised over a lifetime but rather whether you are currently exercising. (Example: Retired professional athletes can go pudgy really fast.)

This finding can be interpreted in two ways: Either what matters is that you meditate and not how much you meditate or it is a local effect; that is, what matters is how much you've meditated in the past few days. One way to find out which interpretation is true is to look for **short-term dose–response relationships**. I found such dose–response relationships for control over attention (correlation of ~0.20 with frequency or number of minutes practiced per day), speed of perception (correlation of ~0.40 with minutes practiced per day), perceived stress (correlation of ~0.20 with mindfulness program adherence), error monitoring (correlation of ~0.35 with frequency of meditation), stress reactivity (correlation of ~0.50 with meditation frequency), trait mindfulness (correlation of ~0.20 for adherence to the mindfulness training), relationship happiness[6] and—in clinical studies—psychological distress (correlation of ~0.15).

The simple message is that it pays to practice more or more often. The effect on trait mindfulness is especially important, given that it is the motor for many other well-being–related effects, as is the effect on stress, given that this might be, for many people, the motivator to start meditating in the first place. The flipside of this finding is that you cannot rest on your meditation laurels, at least for these aspects—it is about how much you practice right now, not how much you have practiced in the past.

There are also effects that do seem to evolve over a **lifetime of practice**. One notable long-term outcome is sustained attention (remember the Ladakh monks and motion-induced blindness?), which also benefits from shorter periods of intense practice, like a retreat, but does not appear to show a short-term dose–response relationship.

There may also be long-term effects for sleep. Early in practice, you have higher levels of alertness and your need for sleep decreases. Over time, your body adapts to this wakefulness and you sleep more efficiently, with shorter periods of shallow sleep and longer periods of deep sleep.

Effects on brain functioning and brain structure fall, almost by necessity, into this category as well. (It is hard to measure day-to-day fluctuations in brain functioning or structure and relate those to the amount of daily practice—it would be prohibitively expensive to do, and the day-to-day changes in the brain are likely too small to be noticeable.)

One very interesting brain change concerns attention. At first, the brain activates its attention centers more and more strongly with advancing practice, and then, after tens of thousands of hours of practice, activation levels drop again. This suggests, as we discussed, an initial slow build-up of attentional effort and then an increasing efficiency in that effort, requiring less activation for the same amount of attention. Higher efficiency can also be seen in a quicker return to focused attention after mind-wandering. Other changes in brain activation concern a growing trend toward disembodiment and selflessness (seen in the supplemental motor areas and the superior medial gyrus) and a less judgmental, evaluative, and emotional stance (less coupling between the anterior cingulate cortex and the lateral orbitofrontal cortex). Finally, meditators' brains become more meditative in daily life—or, at least, they become more meditative when asked to just rest inside the scanner or the lab.

In terms of changes in brain structure, we find increases in volume and/or density in regions of the salience attention network (anterior cingulate cortex, insula; there is also a dose–response relationship here: the total number of accumulated hours correlates with volume/density), in regions that are associated with direct awareness of body sensations (insula, anterior precuneus, sensory and motor cortex; a dose–response relationship with accumulated hours has been found here as well), with global body awareness (supramarginal gyrus), and with emotion regulation (right orbitofrontal cortex, also showing a dose–response relationship with total number of hours accumulated). There are also decreases in volume/density in regions associated with stress reactivity (the subiculum of the hippocampus, showing a dose–response relationship with accumulated hours) and with the narrative self (precuneus). We also saw that true selflessness (i.e., when not just the narrative self but also the self-of-momentary-awareness disappears) is something that takes tens of thousands of hours to cultivate.

One way to summarize these many findings would be to say that the four themes—changes in attention, direct body awareness, global body awareness, and the sense of self—develop slowly over a lifetime of practice, but changes in well-being (such as self-perceived stress, mood, anxiety, emotion regulation, self-concept, trait mindfulness, relationship quality, empathy, and compassion) are mostly linked to local effects of meditation. Perhaps another way of stating this would be to say that the effects that most meditators would be interested in—stress reduction and how meditation affects daily life—are easily acquired and maintained: Just sit! The effects that lead to what Buddhists call awakening or enlightenment (especially a honing and sharpening of sustained attention and increasing levels of selflessness) do take decades to mature.

This, I believe, is a very crucial result. It suggests that we can quite naturally dissociate these two strains of mindfulness—the one geared toward increased personal (and therefore also interpersonal) well-being and the one emphasizing "awakening," "liberation," or "enlightenment"—the gym for the heart and mind can be decoupled from the spiritual exercise. (But note that the spiritual exercise seems to organically incorporate the heart/mind gym.)

The exercise metaphor breaks down here, but yoga could be a good analogy. In the West, yoga has successfully decoupled the physical and well-being aspects of the practice from the spiritual path. (Whether or not that is a good idea depends on who you ask.) In the same vein, mindfulness, as I described at the very beginning of the book, has gradually been turned into a wellness industry. In the process, it has divorced itself from its Buddhist roots, all the while claiming that the benefits remain intact. The available evidence suggests that this may very well be true, as long as we are talking about the local effects of meditation practice.

Whether this is a desirable evolution again depends on who you ask—quite a few Buddhist scholars and teachers[7] rail against what they see as a commodification and appropriation of a venerable tradition. I am less certain that the baby is being thrown out with the bathwater: It seems to me that the effects that can be had from short-term meditation training focused on stress release or other forms of well-being aren't negligible at all and that they might make a real difference in real people's lives. I frankly don't see what is wrong with this, especially when you consider that this sort of practice (unlike many other therapeutic journeys) does not seem to yield as many adverse effects, at least as far as current evidence shows. I, as a card-carrying Buddhist, am very happy that the techniques that I happen to use on my spiritual path have also proven to be helpful to countless others, even if what they are looking for isn't the same as what I am looking for.

This dissociation might also address the fear held by some that meditation is a Buddhist Trojan horse—a way to introduce Buddhist concepts to unsuspecting and potentially unwilling individuals. One thing to immediately point out is that meditation isn't an exclusively Buddhist technique (there are Christian, Hindu, Jain, Jewish, Muslim, and Sikh meditation traditions, among others), although mindfulness meditation is more closely associated with Buddhism than with any other faith tradition. The techniques of mindfulness meditation oriented toward well-being, however, are just as little related to Buddhist concepts and principles as well-being-oriented yoga practices are related to Vedic ideas.

That said, it may be hard to find meditation groups that are non-Buddhist in orientation. I live in Atlanta, and we have two *Vipassanā* groups that I know of, a Tibetan, a Chinese and a Vietnamese monastery, a Shambala center, a Transcendental Meditation® center, at least three Zen groups, and a Plum Village group, all of which offer free meditation instructions and sessions, but I am not aware of any secular group that teaches meditation for free, with the exception of one tea house.

I do feel—and, the more I think about this, the more I realize I feel about this rather strongly—that there could be better efforts at stripping classes in meditation and mindfulness from that religious background; the same is true for meditation peer groups. I have been told that in order to do yoga in the 1960s, you had to find an ashram; now, every strip mall seems to have its yoga studio. Although you need less gear and less instruction to meditate than to do yoga, anyone who meditates could benefit from the support of a good teacher or a group of caring peers. The mindfulness community seems to have fallen a bit short on this account.

Mindfulness from Brain to Mind

One of the questions I asked at the end of Chapter 1 was whether we can trace the effects of meditation all the way from brain activation over structural changes to changes in behavior and psychological make-up. The answer is both "yes" and "no."

One of the vagaries of neuroscience and psychology research is that we live by the grace (or curse) of feasibility. This creates trade-offs. In order to examine the meditating brain in action, we need to look at the professional athletes of mindfulness; in order to be sure that effects are due to the practice per se, we need to look at how practice develops over time. It is impossible to combine both: We simply cannot start a study now and reap the final results in 20 years' time. Thus studies looking at brain activation have been done with very-long-term practitioners, like Buddhists monks, while studies on structural changes in the brain use slightly less accomplished meditators; studies on well-being have often followed newbies over the course of a two-month training program.

On the one hand, we do find good convergence between the two first types of studies: Brain areas that are activated during meditation also tend to show structural changes. This concerns areas associated with the two attention networks (the salience network and the executive network), the sharpening of specific body awareness (related to focus on the breath or on body sensations), the dropping away of a general sense of body awareness, the shushing of the self-as-story, and emotion regulation. Of these, attention and emotion regulation also appear on the list of changes in well-being in both healthy adults and clinical populations.

On the other hand, healthy adults also show effects on personality and immune functioning that are harder to link directly to the brain changes as found in monks and other long-term practitioners. And although it is likely that changes in attention and emotion regulation have effects on stress, rumination, anxiety, depression, and mood, the ties of these psychological changes to brain changes haven't been researched very deeply.

Conversely, one theme that emerged in the brain studies has garnered little interest in the psychological community—the dissolution of the narrative self and of the self-of-momentary-awareness. This may be partially because changes in these aspects of the self are harder to study than, say, changes in well-being or anxiety/depression; we don't have ready-made scales and surveys for these. It may also be because this aspect of meditation is more exclusively Buddhist. As I mentioned in the previous chapter when discussing negative effects of meditation, it may be desirable for a Zen Buddhist to "lose" her self; most people would probably very much like to keep their sense of who and what they are (let alone the sense that they *are* someone) very much intact.

Scientifically Sound Meditation

One conclusion from all this research is that mindfulness makes a person a little bit of a better human being, a little happier, a tad less rough around the edges, and just a bit more pleasant to be around. We also know—at least to some extent—why: The application of mindfulness during meditation gives birth to mindfulness in daily life, which becomes an ingrained habit, and this, in turn, lowers levels of stress, anxiety, or depression; lifts your affect; stops the downward spirals in your mind a bit more easily; and makes you happier. (That is the big picture. We still need to know more about the time course of this cascade, how this works exactly, and if other aspects of your psychological makeup—for instance changes in sustained attention—also play a role in triggering these effects.)

Knowing that meditation and mindfulness are optimizers, can we optimize how we go about optimizing ourselves? That is, can science show us a better way to meditate?

After reading all I could read for this book, and rereading what I wrote, it seems to me that we are a long way off from being able to offer a simple recipe for meditation: Do this, do that, don't do this, and sweetness follows.

Let me try, however, to reiterate some of the findings that might be helpful here. These aren't particularly earth shattering in their newness or brilliance, but it's good to collect them and to note that there are studies to back them up.

A first piece of advice is obvious: **Do meditate**! (Allow me to refrain from enumerating the benefits yet one more time.)

Second, **meditate often** and/or **make your sits a little longer**. There are short-term dose–response effects for outcomes such as attention, perceived stress and stress reactivity, trait mindfulness, relationship happiness, and psychological distress. That is, for these outcomes, we know that it matters how much you have been meditating in the past few days, as opposed to how much you have meditated over your lifetime. That suggests you have to keep up your practice to reap those rewards.

How often or how long should you meditate? We don't really know. The finding that at least some of the effects on well-being are no longer traceable after a few days suggests that meditation should be a daily or near-daily habit, rather than a weekly occurrence. Note that standard MBSR programs, with, on average, 28 minutes of actual meditation per day over an eight-week period, result in nice-sized effects, so this seems like a good dose. The finding that there is a modest positive correlation between practice at home and effect size simply suggests that more is always better.

Should you concentrate your practice and go on meditation retreats? Retreats appear to have their benefits, especially in the area of attention—a more open-minded approach to the world, sharpened visual perception, and a longer attention span. We also know that MBSR programs that include a half-day retreat lead to larger effects on trait mindfulness. Finally, one study found a positive effect of retreats on immune functioning. There are other effects that aren't necessarily benefits and could even be perceived as drawbacks: Retreats increase your chances for unusual body experiences and visual hallucinations, and they may lead to changes in mood (positive, negative, or swinging) or perception of time, and even out-of-body experiences. Britton et al.'s project on unusual experiences (discussed in Chapter 7) also suggests that periods of disorientation or other types of losing touch with reality can have their origins in retreats. The bottom line is that retreats can be times for growth in the practice, but it would be a good idea to monitor yourself for any signs of distress and discuss those with the retreat leaders.

A third piece of advice is to aim for the parasympathetic response, that is: **Relax**! Shoot for a breathing rate of about six seconds per breath: This particular cadence helps synchronize the breath and the heartbeat, which feels particularly relaxing. Because the body settles into such rhythms easily, it might make sense to spend some time at the beginning of each sit to consciously slow down your breath; once that is set in motion, you should be able to coast without thinking about it.[8]

Fourth, there are some **feedback mechanisms** that might help guide your meditation. In Chapter 3, I described a study by Garrison et al. that used brain activation (or, rather, deactivation) in the posterior cingulate cortex (PCC) to guide meditation. Of course, most of us don't have an MRI scanner at hand, but one of the hallmarks of PCC deactivation is "not efforting," and "observing"—not getting lost in feelings, thoughts, or ideas as they arise and simply letting those be. Effortless doing, relaxing, and letting go is thus what settles the mind into the meditative groove: The quality of attention in meditation should be gentle, not forceful. This advice is maybe more useful for already seasoned meditators, however: Garrison et al.'s less experienced participants had trouble deactivating the PCC, even with real-time direct feedback. Another interesting finding from this study was that PCC deactivation feels good: It leaves you more content and more serene, and it gives you more pleasure. So, **leaning in the direction of peace or delight** might be more practical alternative advice. Another feedback mechanism is the presence of *nimittas*, that is, spots of light. (But note that their absence doesn't mean anything: Some people never develop *nimittas*.) You can use the *nimittas* to your advantage: Trying to stabilize or maintain these visual hallucinations and even play with them will likely increase your concentration.

Fifth, one particularly exciting finding is that there is some evidence for a direct transformation from moment-to-moment mindfulness on the cushion to more enduring mindfulness in the actual world outside the meditation room. Given that many of the effects of meditation on well-being are due to increases in trait mindfulness, I would suggest that anything that **fosters mindfulness off the cushion** would be a good idea. This advice is not traditionally a part of Buddhist meditation instructions, but clinical programs do spend a lot of time on exercises that infuse daily life with an open-minded and open-hearted awareness—rightfully so, then, it seems. Such exercises[9] include picking a daily activity that is usually performed mindlessly—something like showering, brushing your teeth, walking the dog, or cooking—and giving it all your attention, or shaking up small parts of your daily routine—take another route to work, don't always order the same thing at your favorite lunch spot, strike up a conversation with a stranger. Take a mindful walk, paying careful attention to everything you see or hear or feel. Perform a random act of kindness and observe what happens. Use your time in the checkout lane or at a red light to reconnect to what is happening inside your body.

Some meditation studies also suggest more specialized pieces of advice. For example, for those who want to achieve "**timeless**" or "**spaceless**" types of meditation, working through the sense of body might be a good route—that is, trying to dissolve the body boundaries might be a good strategy here. As another example, for those who tend to get sleepy, or need re-energizing, **loving-kindness** meditation may be a good remedy. Finally, in Chapter 3, we gathered a nice little bag of **tricks to deal with pain**, either during or outside of meditation: You can focus your attention elsewhere, for instance on the breath; get attuned to and relish in the relaxing effects of meditation; or take an attitude of openness and acceptance toward the true reality of the experience of the pain as it unfolds, moment by moment.

A final word of advice is that although meditation works, and works quickly, it **would be wrong to expect it to work wonders**. It is still *work*—nothing can replace time earnestly spent on the cushion. It is also still not something that will lift you to soaring heights of human flourishing. Although the effect sizes for the typical eight-week interventions are nice, they are in line with what you can expect from other psychological interventions—nothing more, nothing less.

What We Don't Know But Should

The number of studies on mindfulness and/or meditation and how they impact brain, body, and mind is simply staggering. There are still a lot of unknowns, however, and I pointed out a lot of them along the way, at the end of each chapter. I assume most people—including you—have their own wish list of things they would like to know more about than we do now. Here is mine, in no particular order.

First, we still know relatively little about what effects to expect from what types of meditation. Some of the known effects seem self-evident. We saw, for instance, that repeated use of the body scan makes you more sensitive to touch. Experience in the heart practices has an impact on how the brain processes emotion. Over and beyond that, we know little. For instance, compassion training fosters compassion—as expected—but we do not know yet to what extent the more attention-based practices foster compassion too. As another example, open monitoring and focused attention do not seem to lead to different long-term signatures in the brain. This could mean that differences between the attention-based meditation traditions are smaller than we typically think—in other words, meditation is meditation. Maybe it's the case that there is a small set of crucial ingredients that all mindfulness traditions share and these inscribe themselves into the brain with greater force than the more tradition-specific ingredients, making the latter hard to detect.

Second, although we know that there is a cascade where meditation promotes mindfulness, which in turn promotes well-being, we do not know if the cascade is really an automatic, mechanistic process. That is, it is unclear whether meditation by necessity (and in all people) leads to lower levels of stress, a better emotional life, and greater interpersonal happiness. We saw that some of these effects do appear to have brain correlates (in Chapter 4, I called them side effects of meditation), but at least some of these effects may be part of a self-fulfilling prophecy: If you sign up for a stress reduction program, wouldn't you expect your stress levels to go down? This question seems more pressing with regard to outcomes that seem further removed from the attention-training aspect of meditation, such as stronger romantic relationships or a growing sense of selflessness. Do those, indeed, come about as a direct effect of meditation experience?

Third, although it seems indeed as if attention training brings about changes in mindfulness, we still know very little about how that actually works. At some point, there seems to be a jump from learning how to focus on your breath to no longer being bothered when someone cuts you off in traffic. How exactly are those two connected?

Fourth, we know a lot about very long-term meditators, and we likewise know a lot about short-term interventions, but we have almost no data on what happens in between these two extremes—a meditator's development between 50 hours and a few thousand hours of practice. It seems to me that this is a crucial period, where you hone your attention skills, figure out what works for you and what doesn't, learn to act (or not act) accordingly, and—if you are working within a particular system, tradition, or lineage—where you go through the different exercises prescribed by your system, tradition, or teacher. It would be interesting to find out if this is a gradual process or a process that goes through different stages. As I mentioned in the conclusion to Chapter 3, we currently have little evidence for steps, plateaus, or sudden jumps in practice, but maybe that is because we haven't been looking where we should: in these intermediate stages of practice. (One exception is the one study on selfless meditation, where qualitative changes were found in the way the more or less experienced brain deals with the instruction to meditate selflessly.)

Fifth, I mentioned earlier that we have no recipe for meditation. Maybe it would be good to see if we can concoct one. Is more always better, or is there an optimal duration? Are there diminishing returns for longer sits? I also note that MBSR—the program that inspired most current meditation programs—is a hybrid of different meditation techniques, some yoga, and a few additional exercises. We do not know what happens when the balance of these ingredients is changed, when certain parts are omitted, or when we present the program in abbreviated form.

Sixth, even if we could find a recipe, it is unlikely that it would suit or satisfy everyone. There are no doubt individual differences in likes and dislikes for particular practices; it seems very plausible that some people might benefit more from one approach than from another. We also know that some people "get it" faster than other people, and we have no idea why that is. To some, this might suggest that we need a cookbook—a collection of recipes that you can try out at your leisure. I personally think that what we ultimately need is a flowchart, where you start from a common stem (probably attention-based practices) and then branch out, given your own goals and inclinations, life's circumstances, and how you react to them.

Seventh, the idea of neural feedback is appealing. Even though it isn't feasible to tap into PCC activation, there might be ways to use, say, EEG signals or other physiological measures to help guide beginners toward the relaxed yet alert stance that is conducive to meditation. There are commercial applications that claim to do this but without research to back up this claim.

Finally, given that the road to enhanced well-being travels through trait mindfulness, and given that not everyone likes to meditate, it would be helpful to discover if there are alternative ways to boost mindfulness—such as the exercises described in the previous section—and if they result in the same effects as meditation.

Final Words

You made it to the final few paragraphs of this book—congratulations!

I don't know why you picked up this book or why you kept reading (or at least skipped ahead to here), but I thank you for taking this journey with me.

If you are a beginning meditator looking for encouragement or a reason to keep meditating, I hope you found it here. If you have never meditated but are looking for a reason to start, I hope you found it here as well. Mindfulness is an amazing, transformative journey—welcome! If you never meditated and were looking for a reason not to, I hope this book informed whatever decision you made. And if you have already been meditating for a while (maybe even a lifetime), I hope you learned something new about how and why the practice is so transformative—I know I learned a lot in the process of writing this book. Of course, much more work remains to be done, and that is fitting: The study of meditation is like meditation itself—a never-ending journey, and who knows where you will end up.

Now, if you'll excuse me: After writing all this, I feel a bit exhausted.

A sit would be nice.

{ NOTES }

Preface

1. The most famous example is the Dalai Lama, for instance in his book *The Universe in a Single Atom.*

Chapter 1

1. This story is described in more detail in Kabat-Zinn (2011). Words in quotes are citations from this paper.

2. The numbers come from Wilson (2014), an excellent source for the history of the concept of mindfulness and the mindfulness movement within the United States, and Pickert (2014).

3. In his study of mindfulness in the United States, Wilson (2014) sees Kabat-Zinn's work (e.g., 1990, 1994, 1998, 2005) as one of three sources of the mindfulness movement as it began to take shape in the 1970s. The two others explicitly self-identified and advertised themselves as Buddhist—one is the Asian-trained pioneers of the American *Vipassanā* or Insight Meditation movement (notably Sharon Salzberg Jacqueline Schwartz, Jack Kornfield, and Joseph Goldstein); the other is the modernist Vietnamese-Zen monk Thích Nhất Hạnh, with the publication of his 1975 book *The Miracle of Mindfulness*.

4. You might think the exception would be mindful sleeping, but Amazon does sell an mp3 with that title.

5. Its impact factor in 2014 was 3.69.

6. Kabat-Zinn (1994, p. 4). A group of psychologists have come up with a slightly wordier consensus definition: "nonelaborative, non-judgmental, present-centered awareness in which each thought, feeling, or sensation that arises in the attentional field is acknowledged."

7. Other teachers—for instance Thích Nhất Hạnh (http://www.lionsroar.com/the-moment-is-perfect/)—prefer oranges or tangerines. When I teach mindfulness classes, I use chocolate; it's my Belgian roots. I also like what chocolate does that a raisin doesn't: melting on your tongue and slowly releasing a wide, long-lasting palette of tastes and aromas. If you know what I am talking about—congratulations, you know what it is to mindfully eat chocolate. If you don't, get yourself to the store *now* and treat yourself to a nice bar of Godiva or Lindt, and try it.

8. Killingsworth and Gilbert (2010).

9. Do note that this study shows that a wandering mind is an unhappy mind, but the direction of the causality—that is, does the wandering mind make you unhappy, or does unhappiness make your mind wander?—hasn't been established yet, so maybe I am a bit forceful with my interpretation here.

10. A Buddhist source for this comparison is the *Assutavā Sutta*.

11. A trait is a more or less lasting quality in a person that can help distinguish that person from another, because people differ in the amount of it. For instance, intelligence is a trait—some of us have more of it than others. So is introversion—some people are more introverted than others. Vision, on the other hand, is not a trait—barring physiological damage, we can all see.

12. For instance, the Mindful Attention Awareness Scale (Brown & Ryan, 2003), the Kentucky Inventory of Mindfulness skills (Baer et al., 2004), the Freiburg Mindfulness Inventory (Walach et al., 2006), and the Five-Facet Mindfulness Questionnaire (Baer et al., 2006)—the five facets in the latter survey are observing, describing, acting with awareness, nonjudging of inner experience, and nonreactivity to inner experience.

13. There is quite some controversy around this conceptualization. One criticism is that it is quite narrowly focused on attention (leaving out, e.g., the social, affective, and ethical aspects of the Buddha's original conceptualization). Another is that it relies too much on subjective self-report and not on objective, outside measures. There is also a criticism that mindfulness scales might be approached differently by those who are trained in mindfulness (and thus know the lingo) than by those who are not. That would make direct comparisons between these two groups problematic. For a good review of these and other criticisms, see Grossman and Van Dam (2011). There have been some attempts to use more objective measures, such as the accuracy of breath counting (Levinson et al., 2014), but these methods have not been widely adopted. The traditional mindfulness scales, flaws and all, are for now the standard tool used in research (e.g., Grossman & Van Dam counted no less than 350 papers looking into the three most-often used scales published between 2004 and 2009).

14. Kabat-Zinn (2011).

15. Zen is a form of Buddhism practiced in Japan, Korea, China, and Vietnam; *Theravāda* is a form of Buddhism practiced in Cambodia, Laos, Thailand, Myanmar, and Sri Lanka.

16. See the *Satipaṭṭhāna Sutta* and *Ānāpānasati Sutta*. I grossly oversimplify these instructions here, of course.

17. A good quick overview can be found in Lutz et al. (2008). Guided audio meditations can be useful if you are new to this. Many links for different styles of meditation can be found at https://contemplativemind.wordpress.com/how-to-meditate-links-for-guided-meditation-practice/.

18. Some would argue that the body scan also has an open monitoring quality to it.

19. A nice, 10-minute guided body scan meditation can be found at https://www.youtube.com/watch?v=zsCVqFr6j1g.

20. Buddhists will often include all "sentient beings" in that circle. It is not a bad idea to include your pets in this type of meditation.

21. A good introduction can be found in Fischer (2013) or Trungpa (2010).

22. Ozawa-de Silva and Dodson-Lavelle (2011).

23. As described in his books; see also Santorelli (2014).

24. Segal et al. (2002). Williams also co-wrote a self-guided mindfulness-training book (Williams & Penman, 2011) that uses many of the same ideas.

25. Linehan (1993).

26. Hayes et al. (1999). Note that although ACT is often included in lists of mindfulness-based interventions (e.g., Chiesa & Malinowski, 2011), Hayes himself does not acknowledge the similarity.

27. https://www.resource-project.org/en/home.html.

28. http://ccare.stanford.edu/education/about-compassion-cultivation-training-cct/.

29. Goyal et al. (2014).

30. *Web of Science* search on the topic of "mindfulness" (August 2015).

31. http://www.tricycle.com/blog/meditation-nation.

32. Inevitably, the pendulum has started to swing, and *The New York Times* (http://op-talk.blogs.nytimes.com/2014/06/30/the-mindfulness-backlash/) and *The Huffington Post* (http://www.huffingtonpost.com/2015/03/16/mindfulness-backlash_n_6800924.html) have now discovered a mindfulness backlash—doubts about the strength of the evidence and the discovery of a possible dark side—see the end of Chapter 6—as well as criticism from a small host of Buddhist scholars and teachers.

33. http://www.dalailama.com/messages/transcripts/10-questions-time-magazine.

34. In this book, I use positive effect sizes to indicate that things are looking up for meditators. So an effect of 1 *SD* on stress would mean that meditating makes you less stressed; an effect size of –1 *SD* would mean it stresses you out more.

35. Cohen (1988).

36. Sanmuganathan et al. (2001).

37. Lipsey and Wilson (1993).

38. Although I would assume that few meditators are likely to be in the bird-killing business.

39. In all meta-analyses, studies were weighted for sample size.

40. Kabat-Zinn (2011, p. 288).

Chapter 2

1. Jevning et al. (1992).

2. This book isn't meant as a manual on mediation and the different traditions. A good overview can be found, for instance, in Goleman (1996).

3. Beary et al. (1974), Tang et al. (2009). Note that different practices have different emphases, so this does not happen in all mediation systems (e.g., nonreferential compassion mediation, as we will see in Chapter 3, is invigorating rather than relaxing), nor does it necessarily happen to all meditators, even in traditions that emphasize this type of quieting of body and mind.

4. Fenwick et al. (1977).

5. Lazar et al. (2005).

6. Cysarz and Büssing (2005).

7. Berntson et al. (1993)

8. Chang and Lo (2013).

9. Wu and Lo (2008).

10. Jevning et al. (1992).

11. Kornfield (1979).

12. Pagano et al. (1976), Younger et al. (1975).

13. Gallois (1984).

14. Travis and Wallace (1997).

15. Wolkove et al. (1984).

16. Gallois (1984).

17. Gallois (1984).

18. www.tm.org/inner-peace; Badawi et al. (1984), Farrow and Hebert (1982), Travis and Wallace (1997).

19. Badawi et al. (1984).

20. As far as I know, there are two studies on this: Lehrer et al. (1999) and Phongsuphap et al. (2008).

21. Jovanov (2005), Kitney and Rompelman (1980).

22. David-Néel (1929).

23. Benson et al. (1982, 1990).

24. Kozhevnikov et al. (2013).

25. "Fired" is neuro-speak for transmitted a signal, that is, "worked."

26. Higher amplitude means that brainwaves get more prominent.

27. For an excellent overview on this work, see Cahn and Polich (2006).

28. The term and method (at least in its current usage) was pioneered by Varela (1996).

29. Broks (2003).

30. It is not quite, then, like getting your head checked by a jumbo jet, but it is close.

31. Uttal (2001).

32. Kanwisher et al. (1997), Sergent et al. (1992).

33. Laird et al. (2011), Smith et al. (2009).

34. Raichle et al. (2001).

35. Bar et al. (2007).

36. Buckner et al. (2008).

37. Andrews-Hanna et al. (2010).

38. Originally discovered by Seeley et al. (2007); see Bressler and Menon (2010) for an overview.

39. Corbetta et al. (2008).

40. Hasenkamp et al. (2012).

41. For instance, Braboszcz et al. (2010), Cahn and Polich (2006), Chiesa and Serretti (2010), Deshmukh (2006), Fox et al. (2014), Jerath et al. (2012), Newberg (2014), Ott et al. (2011), Sperduti et al. (2012), Tang et al. (2012), Tomasino et al. (2012), Vago and Silbersweig (2012).

42. Tomasino et al. (2013).

43. Sperduti et al. (2012).

44. As this book is going to press, a third meta-analysis, by Fox and colleagues (2016) has been published, covering mostly the same territory as the Tomasino analyses but adding new studies, primarily in open monitoring and loving-kindness. Tomasino's map primarily highlights focus-attention and mantra-recitation studies.

45. Laird et al. (2005).

46. This is, I would argue, one of the deeper mysteries of the psyche: Why, when we instruct our mind so politely to stay focused, does it simply refuse to comply? It isn't as if it goes on to dwell on matters of great concern—in my morning meditation, I often catch myself wondering about what to wear to work, and I wear a black blazer, a black t-shirt, and black jeans just about 98% of the time.

47. This number of hours is self-reported by the participants and is thus an estimate, of course.

48. Note that Tomasino does not explicitly categorize her results in this way. Her interest lies in identifying a meditation network (actually, one for meditation in general, one for

focus-attention meditation, and one for mantra meditation). At this point in this book, it makes sense to me to relate the regions she identified in those networks to broader known brain networks, such as the networks I described earlier—just to see what is there. Hölzel et al. (2012) offer the same categorization as I use here, with the addition of emotion regulation; another overview paper on the neuroscience of meditation (Tang et al., 2015) sees an impact of meditation on attention control, self-awareness, and emotion regulation. I see little evidence for emotion regulation in Tomasino's map. Note that this is to be expected: This map deals with activations *during* mediation in very experienced meditators (who might have very little negative emotion to regulate during their session in the scanner). There is, however, evidence for emotion regulation in studies that have looked at structural changes in the brain, as we shall see.

49. Spreng et al. (2013).

50. Esslen et al. (2008).

51. Kircher et al. (2002), Kjaer et al. (2002).

52. Esslen et al. (2008), Northoff et al. (2006), van der Meer et al. (2010).

53. Kim and Johnson (2014).

54. Fossati et al. (2003).

55. Phan et al. (2003).

56. For example, Alidina and Marshall (2013), Salzberg (2010).

57. Lou et al. (1999).

58. Blanke et al. (2005).

59. Penfield and Erickson (1941).

60. Kornfield (1979).

61. Kornfield doesn't mention how many.

62. Salardini et al. (2012).

63. Haggard and Whitford (2004).

Chapter 3

1. Bærentsen et al. (2010).

2. Hasenkamp et al. (2012).

3. Brewer et al. (2011), Froeliger et al. (2012), Josipovic et al. (2012).

4. This may be taking us too far, but in case you were wondering why the coupling is positive: If you look at this at short time scales, the coupling is negative (default-attention-default-attention). Over the long run, however, the coupling is positive: Each time you get distracted, attention kicks in.

5. Garrison et al. (2013).

6. Note that Garrison did not use the resting state as the baseline task. Rather, in her baseline task, participants were shown a list of adjectives and were asked to think about and decide whether the words described them. This task is known to activate the crucial brain region of interest in this study, the posterior cingulate cortex; this was done to provide a more comparable baseline between meditators and nonmeditators—as we will see, meditators often show more meditation-like activation during resting states.

7. The PCC isn't on Tomasino's map, but it is intimately linked to the precuneus, which is.

8. All these examples are direct quotations from Garrison (2013) et al.

9. Wang et al. (2011).

10. Craig (2005).

11. Kornfield (1979).

12. Lutz et al. (2008).

13. Manna et al. (2010).

14. Brewer et al. (2011).

15. For contemporary accounts, see Brahm (2006), Brasington (2015), Catherine (2008), or Shankman (2008, 2015).

16. Hagerty et al. (2013).

17. Berkovich-Ohana et al. (2013).

18. Note that this study was not done inside an MRI scanner but a MEG scanner, which measures the magnetic fields produced by the electrical activity of the brain. The researchers found that all interesting effects occurred in brainwaves of very low frequencies, 4 to 7 Hz, so-called theta waves. Theta waves are often found in sleepy, drowsy, or meditative states but not during deep sleep. It isn't clear what causes these theta waves or what their significance is. Some have argued that theta indicates relaxed attention turned inward.

19. An alternative story, suggested by one of the reviewers, is that the temporal parietal junction is associated with agency, empathy, perspective-taking in social situations, as well as reorienting attention (Decety & Lamm, 2007). This would then mean that timelessness and spacelesness can also be described as a relinquishing of agency, increasing distance from the social world, and a tendency for attention to stay where it is.

20. Note that, in Buddhist circles, it is somewhat taboo to discuss your meditation experiences outside the teacher–student relationship, so meditators rarely hear about others' intimate experiences during meditation.

21. Lindahl et al. (2014).

22. For instance in the 5th-century meditation manual *The Path of Purification* by Buddhaghosa.

23. Gyatso (2004).

24. For instance, Sayadaw (1994).

25. Austin (1999).

26. Brahm (2006), Catherine (2008).

27. Namdak (2006).

28. Mason and Brady (2009). One popular-science account of this study in the magazine *Wired* was titled: "Out of LSD? Just 15 Minutes of Sensory Deprivation Triggers Hallucinations." Note that, in this study, a few of the participants did experience quite a bit of paranoia, like sensing an evil presence in the room—bad trips are apparently another possibility that LSD and perceptual isolation have in common.

29. Lloyd et al. (2012).

30. Boroojerdi et al. (2001).

31. ffythe et al. (1998).

32. Lo et al. (2003).

33. Lloyd et al. (2012).

34. For example, Brahm (2006).

35. Anand et al. (1961), Banquet and Sailhan (1974), Barwood et al. (1978), Becker and Shapiro (1980), Cahn et al. (2013), Fenwick et al. (1977), Hiray (1974), Kasamatsu and Hirai

(1966), Kumar et al. (2010), McEvoy et al. (1980), Orme-Johnson (1973), Telles and Naveen (2004), Telles et al. (1994), Younger et al. (1975).

36. Levenson et al. (2012).

37. Gard et al. (2012), Grant and Rainville (2009), Kakigi et al. (2005), Lutz et al. (2013), Perlman et al. (2010), Zeidan et al. (2010), Zeidan et al. (2011). A detailed overview can be found in Grant (2014).

38. Other studies, outside the meditation sphere, have shown that slow breathing can decrease both feelings of pain intensity and pain unpleasantness (e.g., Zautra et al., 2010).

39. Grant and Rainville (2009).

40. Zeidan et al. (2010).

41. Kakigi et al. (2005).

42. Lutz et al. (2012, p. 539).

43. Lutz et al. (2012), Zeidan et al. (2011).

44. A great introduction can be found in Gallagher (2000); more extensive accounts are given in Damasio (2010), Dennett (1991), and Metzinger (2004).

45. For instance, Gazzaniga (1998).

46. Appropriately (or inappropriately) named Dogen, by the way.

47. Farb et al. (2007).

48. For a similar result with an eight-week MBSR program, see Kerr et al. (2011).

49. Esslen et al. (2008), Walla et al. (2007).

50. Dor-Ziderman et al. (2013).

51. Wiebking et al. (2011).

52. Dor-Ziderman et al. (2013).

53. MEG measures the magnetic fields inside the brain. These magnetic fields originate from the electrical currents in the brain.

54. Lutz et al. (2007, p. 539).

55. Persinger (1983). His "God spot" is located in the temporal lobes.

56. Lutz et al. (2008, 2009).

57. In this meditation, they were trying to attain a state of 'pure compassion' or 'non-referential compassion'—a feeling of altruistic love and compassion towards all beings.

58. For instance, Goldstein (2013).

59. Engström and Söderfeldt (2010).

60. Lee et al. (2012).

61. Brewer et al. (2011).

62. Liddell et al. (2005).

63. Garrison et al. (2014).

64. Fan et al. (2011).

65. Manna et al. (2010).

66. Baron Short et al. (2010).

67. Brefczynski-Lewis et al. (2007).

68. Hasenkamp and Barsalou (2012).

69. For instance, Omata et al. (2013).

70. For instance, Nakao et al. (2003), Nestoriuc and Martin (2007), Nestoriuc et al. (2008).

71. Cahn et al. (2010).

72. Dor-Ziderman et al. (2013).

Chapter 4

1. Maguire et al. (2000).

2. Draganski et al. (2004).

3. Hutton et al. (2009), Testa et al. (2004).

4. Fox et al. (2014).

5. Fox et al. (2014).

6. There are a few studies that simply mention that "some" of the participants have been included elsewhere, so the exact number is unknown.

7. This is the group of longitudinal studies.

8. This is officially called the "file drawer" problem—many researchers have unpublished data sets, simply because they don't think there's anything interesting there.

9. There can be a host of other reasons why reviewers reject a paper—the methodology may be unsound, they might not think you answered your research question well, or—as authors like to think—the reviewer woke up in a particularly evil mood that day.

10. Vestergaard-Poulsen et al. (2009).

11. Leung et al. (2013).

12. In neuroscience circles, this effect is often called "what fires together, wires together."

13. Burgess et al. (2007), Koechlin (2011).

14. One reason why it might not show up on Tomasino's map is that activation in this region is harder to measure with fMRI, due to signal dropout in this area.

15. Schoenbaum and Esber (2010).

16. Goldin et al. (2008), Ochsner et al. (2004).

17. Fox et al. (2014), Luders et al. (2009).

18. Brefczynski-Lewis et al. (2007), Goldin and Gross (2010), Lou et al. (1999), Pagnoni et al. (2008).

19. Austin (2009).

20. Hölzel et al. (2011b) make largely the same points.

21. For an overview on this topic, see Davidson et al. (2002).

22. Luders et al. (2013).

23. Herman and Mueller (2006), McNaughton (2006), O'Mara (2005).

24. Conrad (2008).

25. Lazar et al. (2005), Pagnoni and Cekic (2007). A nice review can be found in Luders (2014).

26. Makris et al. (2005).

27. Luders et al. (2011).

28. Their measure was fractional anisotropy.

29. Note that not all studies that could report a correlation do so. This could mean anything—researchers didn't do the analysis, or they did but did not find a relationship and didn't find this noteworthy enough to report, or they did find a relationship but for some reason left this out of their paper.

30. Fox et al. (2014) summarize these results in their Table 6. Unfortunately, they only tabulate significant results and do not mention studies that report that a particular region is not associated with morphology. I added those studies back into the mix.

31. Farb et al. (2013), Hölzel et al. (2010), Hölzel et al. (2011a)—the latter two report data from the same study.

32. Tang et al. (2010), Tang et al. (2012). The latter reports results halfway through training, that is, after a mere five hours of meditation experience.

33. For instance, Chaddock-Heyman et al. (2013), Olesen et al. (2003).

34. Grant et al. (2010).

35. The investigators looked at these brain regions specifically, because these are generally associated with pain perception and pain sensitivity.

36. Singleton et al. (2014).

37. The pontine tegmentum, locus coeruleus, nucleus raphe pontis, and the sensory trigeminal nucleus. Note that Hölzel et al. (2011a) found changes in some of the same regions.

38. More specifically, on scales that measured self-acceptance, environmental mastery, autonomy, a sense of purpose in life, and personal growth.

39. Hölzel et al. (2010).

40. Tang et al. (2012).

41. Cole et al. (2012), Kieseppä et al. (2010).

Chapter 5

1. Kabat-Zinn (1994, p. 4).

2. Or whatever the basic attention practice in your given mindfulness tradition is.

3. Sedlmeier et al. (2012).

4. Ebert and Sedlmeier (2012).

5. Hasenkamp et al. (2012); for a similar model, see Malinowksi (2013).

6. This is often also called "selective" attention—focusing on a single thing at a time.

7. Allen et al. (2012), Anderson et al. (2007), Chan and Woollacott (2007), Jensen et al. (2012), Kozasa et al. (2012), Lykins and Baer (2009), Moore et al. (2012), Moore and Malinowksi (2012), and Teper and Inzlicht (2013). I excluded one study (Wenk-Sormaz, 2005), because it used a short-lived intervention: Nonmeditators were meditating on the breath for 20 minutes right before doing the Stroop task.

8. Teper and Inzlicht (2013) and Chan and Woollacott (2010), respectively.

9. Allen et al. (2012), Heeren et al. (2009), Jensen et al (2011), Jha et al. (2007; this study compares two types of meditation interventions with a control group), Sahdra et al. (2011).

10. Allen et al. (2012).

11. Olivers and Nieuwenhuis (2005, 2006).

12. Slagter et al. (2007), van Leeuwen et al. (2009), van Vugt and Slagter (2014).

13. Van Vugt and Slagter (2014).

14. Hodgins and Adair (2010).

15. Van den Hurk et al. (2010).

16. Teper and Inzlicht (2013).

17. van Leeuwen et al. (2012).

18. A millisecond is 1/1000 of a second.

19. P1 and N1, for the ERP aficionados among you.

20. The same researchers also looked at six focused-attention meditators (with, on average, three years of meditation experience) before and after an intensive four-day open-monitoring retreat. They found that the meditators were faster for the smaller digits before the retreat (the researchers ascribed this to their focused-attention habits, which favor a narrow "aperture"); after the retreat, they were balanced in their response times. This

suggests that the open-minded outlook on life (at least life as it plays on the computer screen) can be trained relatively quickly and that the type of meditation one engages in might matter—open-monitoring experience leads to more open awareness. This is a *very* small-scale study, however, and I therefore hesitate to include this in the main text (which is why you are reading about this in this endnote).

21. Valentine and Sweet (1999).

22. Jensen et al. (2011).

23. MacLean et al. (2010).

24. Anderson et al. (2007), Banks et al. (2015), Jha et al. (2015), MacLean et al. (2010), Morrison et al. (2014), Mrazek et al. (2013), Sahdra et al. (2011).

25. Carter et al. (2005). I did not include this study in the previous group of seven studies because its methods and subject sample are atypical.

26. I suggest you get out your own pair of red/green 3D glasses. Then Google this phenomenon for a few examples. Be prepared to be amazed.

27. Alterations were self-reported. We'll assume here that monks don't lie.

28. Again, please Google for examples.

29. Again, assuming that monks do not lie in their self-reports.

30. Jensen et al. (2011).

31. Daubenmier et al. (2013).

32. Khalsa et al. (2008), Melloni et al. (2013).

33. Fox et al. (2012), Mirams et al. (2013).

34. The authors used discrimination thresholds, areas devoted to the body region in the primary sensorimotor cortex, and a combination of these two as their objective measures of sensitivity.

35. Naranjo and Schmidt (2012).

36. Bornemann et al. (2014).

37. Sze et al. (2010).

38. Given that two studies suggest that meditators aren't better at detecting heart rate, it may be possible that they picked up on their embodied emotions through some other route. As we have seen in Chapter 2, the arousal system has a broad range of symptoms, including—besides a heart beating faster—shallower breathing, excessive sweating, and the like.

39. This work focuses on women, because this particular issue is a more common problem for women than for men, possibly because the physiological signals for sexual arousal in males—particularly, erections—are less ambiguous.

40. Dove and Wiederman (2000).

41. Brotto and Basson (2014), Brotto and Heiman (2007), Brotto et al. (2008, 2012a, 2012b, 2013, 2014, 2015); one additional study is Silverstein et al. (2011).

42. Brotto et al. (2012b).

43. Both reported in Hucker and McCabe (2014).

44. Brotto et al. (2008).

45. Silverstein et al. (2011).

46. For instance, Glicksohn (2001).

47. My new trick is to set an actual timer. Even though I have done this now dozens of times, I am often still surprised when it rings—showing that time passes by more quickly than I was anticipating.

48. Woodrow (1951, p. 1231).

49. Either by having people compare the length of two time durations or by having them recreate the time duration of a beep. This is all on relatively short time scales—from half a second to half a minute.

50. Berkovich-Ohana et al. (2011).

51. Wittmann et al. (2015).

52. Kramer et al. (2013).

53. Droit-Volet et al. (2015).

54. Sucala and David (2013).

55. Wittman et al. (2015).

56. Banks et al. (2015), Chambers et al. (2008), Jha et al. (2010), Morrison et al. (2013), Mrazek et al. (2013).

57. Heeren et al. (2009), Zeidan et al. (2010).

58. Mrazek et al. (2013).

59. I suspect this is for two reasons: (a) There aren't a lot of studies out there yet, and (b) the few studies on the topic all use different measures.

60. Mitchell et al. (2015).

61. The studies were Bögels et al. (2008), Carboni et al. (2013), Fleming et al. (2015), Haydicky et al. (2012), Haydicky et al. (2015), Hepark et al. (2014), Hirvikoski et al. (2011), Mitchell et al. (2008), Mitchell et al. (2013), Pettersson et al. (2014), Philipsen et al. (2007), Schoenberg et al. (2014), Singh et al. (2010), van de Weijer-Bergsma et al. (2012), van der Oord et al. (2012), and Zylowska et al. (2008).

62. Bögels and Restifo (2014).

63. Mitchell et al. (2015).

64. Schoenberg et al. (2014).

65. Bögels et al. (2008), van de Weijer-Bergsma et al. (2012), van der Oord et al. (2012).

66. Fleming et al. (2015), Petterson et al. (2014), Zylowska et al. (2008).

67. Because the studies on nonjudgmental alerting used such diverse methods and measures, I did not dare throw them all in a single meta-analysis.

68. For instance, Chiesa et al. (2011).

Chapter 6

1. Clarke et al. (2015, p. 14).

2. Emphasis added.

3. Sears et al. (2011).

4. Effects on attention were, of course, covered in the previous chapter.

5. That's why I ask our seven-year old to deliver me my dad report card from time to time—he has a direct and much more objective outlook on my socioemotional failings as a parent than I do. He also has a keen interest in seeing them remedied.

6. There are many types of relaxation therapy. The two most popular ones are autogenic relaxation (where you learn to couple restful visual imagery with an awareness of its calming effects on the body; e.g., you could imagine a peaceful setting, like a beach, and focus on deliberate, slow, relaxed breathing, or on relaxing your limbs one by one) or progressive muscle relaxation (where you learn to slowly tense and then relax particular muscle groups one by one).

7. A key element here is that the participants shouldn't suspect that they are part of a placebo intervention, which isn't always easy to pull off.

8. Kirsch et al. (2008), Rief et al. (2009).

9. Malarkey et al. (2013); this was, however, a clinical study so is not covered in this chapter but in the next.

10. Chiesa and Serretti (2009).

11. Sharma and Rush (2014).

12. Aikens et al. (2014), Amutio et al. (2015), Banks et al. (2015), Gallego et al. (2014), Kemper et al. (2015), O'Leary and Dockray (2015), Pace et al. (2009), Phang et al. (2015), Song and Lindquist (2015), Sood et al. (2014), Taylor et al. (2014), Van Gordon et al. (2014).

13. Geary and Rosenthal (2011), Phang et al. (2015), Shapiro et al. (2011).

14. Pace et al. (2009)

15. Flook et al. (2013), Nyklíček et al. (2013), Pace et al. (2009). There are also a few studies looking at clinical groups; the one review on this topic (O'Leary et al., 2015) finds the evidence inconclusive and notes that controlled studies show no effect.

16. Davidson et al. (2003).

17. Alternatively, an immune-system boost might lead to increased happiness.

18. Creswell et al. (2009), Robinson et al. (2003).

19. Witek-Janusek et al. (2008).

20. Jacobs et al. (2011).

21. Goyal et al. (2014), Winbush et al. (2007).

22. Britton et al. (2010), Ferrarelli et al. (2013), Kaul et al. (2010), Pattanashetty et al. (2010). As usual, I did not include studies on meditation or meditation-related practices that do not focus on mindfulness, such as Transcendental Meditation®, which is based on the internal repetition of a mantra, or forms of yoga.

23. All these numbers are averaged over the three studies that provided them (the four listed in the previous note minus Kaul et al., 2010). Note that the findings aren't necessarily consistent between studies. For instance, Britton et al. (2010) find *less* slow-wave sleep in their meditators.

24. Britton et al. (2014).

25. Sedlmeier et al. (2012).

26. I also relied on Sedlmeier et al.'s (2012) calculations for the effect sizes of individual studies. They use the correlation coefficient as their metric of effect size; I transformed these to the metric I have been using throughout this book, the mean standardized difference, so that the numbers I report here are directly comparable to the other effect sizes reported in this book.

27. To make matters even more complicated, Eberth and Sedlmeier (2012) also published a separate meta-analysis on mindfulness meditation alone, that is, almost the same subset of the Sedlmeier et al. (2012) studies as the one I used here. Their analysis, however, also excludes active control groups, which I felt should be part of the picture.

28. Thirty-nine studies in Eberth and Sedlmeier (2012).

29. For example, Ryff (1989).

30. MacKenzie et al. (2006), Morone et al. (2008), Nyklíček and Kuipers (2008), Ortner et al. (2007), Sauer et al. (2011b).

31. Chang et al. (2004), Kirsch and Henry (1979), Lin et al. (2008), Shapiro et al. (1998, 2007), Tacon et al. (2003).

32. Anderson et al. (2007), Astin (1997), Chambers et al. (2005), Chang et al. (2003), Greene and Hiebert (1988), Lynch et al. (2011), Sauer et al. (2011), Sears and Kraus (2009), Shapiro et al. (1998, 2007).

33. Lin et al. (2008).

34. Anderson et al. (2007), Chambers et al. (2008), Lynch et al. (2011), Oken et al. (2010), Sauer et al. (2011b), Shapiro et al. (1998).

35. Anderson et al. (2007), Nyklíček and Kuipers (2008), Ortner et al. (2007), Sears and Kraus (2009), Shapiro et al. (2007), Sze et al. (2010).

36. Carson et al. (2004), Chu (2010), MacKenzie et al. (2006), Oken et al. (2010), Oman et al. (2007), Ortner et al. (2007), Sauer et al. (2011a), Sears and Kraus (2009), Walach et al. (2007).

37. Mor and Winquist (2002).

38. Kuehner and Weber (1999), Nolen-Hoeksema. (2000).

39. Spasojeviç and Alloy (2001).

40. Remember that I use positive effect sizes to show "positive" effects, in the sense of effects that would be good to experience, so a positive effect on rumination means that people ruminate less.

41. Astin (1997), de Grâce (1976), Jain et al. (2007).

42. Capacity for status is a combination of ambition and self-assurance—the kind of cockiness that is rewarded with status in our society. Maybe Sedlmeier is showing his ideological cards a bit by calling this a negative trait.

43. There is only a single study that I am aware of (van den Hurk et al., 2011) that compares a more complete personality profile of meditators and nonmeditators; this study uses the NEO inventory. Within the group of meditators, those who had been practicing longer were more open to experience, more extraverted, less neurotic, and less conscientious (no difference in agreeableness). The sample size is small here (35 in each group), and because it is the only study of its kind, I found it more prudent to mention it in this footnote rather than in the main text.

44. Ortner et al. (2007), Sze et al. (2010), Tacon et al. (2003), van den Hurk (2011).

45. I treat trait mindfulness here as a one-dimensional concept. Some scales attempt to measure more than one facet of mindfulness, particularly the Five Facet Mindfulness Questionnaire, which has the five facets of observing, describing, acting with awareness, nonjudgment, and nonreactivity. In the case of multi-facet scales, I used the total score on those different subscales. I do this partially to make a complicated story somewhat more digestible, partially because some researchers (e.g., Aguado et al. 2005; Tran et al., 2013) have found that one or two dimensions do suffice to explain mindfulness, at least in meditators.

46. Carson et al. (2004), Chambers et al. (2008), Grant and Rainville (2009), Hölzel et al. (2011a), Jensen et al. (2011), Klatt et al. (2009), Lynch et al. (2011), Moore and Malinowski (2013), Nyklíček and Kuipers (2008), Oken et al. (2010), Ortner et al. (2007), Sauer et al. (2011a), Sauer et al. (2011b), Shapiro et al. (2007), Shapiro et al. (2008), Sze et al. (2010).

47. Kiken et al. (2015).

48. Measured with the Toronto Mindfulness Scale. Sample questions: "I noticed subtle changes in my mood," "I was open to taking notice of anything that might come up."

49. Alexander et al. (1989), Astin (1997), de Grâce (1976), Kirsch and Henry (1979), Oken et al. (2010), Ortner et al. (2007), Shapiro et al. (2007).

50. Chu (2010).

51. Carson et al. (2004). Note that, in the spirit of this research, the two main authors of this study appear to be married to each other.

52. Lesh (1970), Shapiro et al. (1998).

53. Batson et al. (1987), Eisenberg et al. (1989). One meditation study (Klimecki et al., 2013a) found that empathy training increased negative affect when participants were shown videos of human suffering.

54. I apologize to fellow baby-boomers for the bad late 1970s hair-rock flashback.

55. Keltner and Goetz (2007).

56. Used in McCall et al. (2014) and Weng et al. (2013).

57. Fredrickson et al. (2008), Jazaieri et al. (2013), Neff and Germer (2013), Weng et al. (2013).

58. There are also studies that have concluded that compassion training has positive aspects on other aspects of well-being such as responses to emotional stimuli (Desbordes et al., 2012), affect (Klimecki et al., 2013a, 2013b), prosocial behavior (i.e., behavior explicitly meant to benefit another; Leiberg et al., 2011), and empathy (Mascaro et al., 2013a). Compassion training also reverses the empathic distress that can result from empathy training (Klimecki et al., 2013b).

59. McCall et al. (2014).

60. https://www.resource-project.org.

61. McCall et al. (2014).

62. Lipsey and Wilson (1993). The effects here are all comparisons between interventions and their control groups. Listing all 156 would take this too far, but it includes multiple forms of psychotherapy, behavioral therapy, counseling, biofeedback, organizational interventions, interventions to improve education and instruction, remedial language programs, and so on.

63. It is also the question for policymakers to ask: What is the most time- or cost-efficient way to achieve a given desired result?

64. Jain et al. (2007).

65. Kirsch and Henry (1979).

66. Visted et al. (2015).

67. Phang et al. (2015), Shapiro et al. (2008), Snippe et al. (2015), Vieten and Astin (2008), Wallmark et al. (2013).

68. Weighted for sample size.

69. de Vibe et al. (2013), Krusche et al. (2013), Phang et al. (2015), Shapiro et al. (2007), Shapiro et al. (2008), Vieten and Astin (2008), Wallmark et al. (2012).

70. Weighted for sample size.

71. Shapiro et al. (2008).

72. A few can be found in Baer (2003), Brown et al. (2007), Chiesa et al. (2013), Creswell and Lindsay (2014), Grabovac et al. (2011), Hölzel et al. (2011b), Segal et al. (2013), Shapiro et al. (2006), and Vago and Silbersweig (2012).

73. Bao et al. (2015), Birnie et al. (2010), Black et al. (2011), Coffey et al. (2010), de Vibe et al. (2015), Evans and Segerstrom (2011), Garland et al. (2015), Gauthier et al. (2015), Gregorio and Pinto-Gouveia (2013), Haver et al. (2015), Moore and Malinowksi (2009), Ortner et al. (2007), Prakash et al. (2015), Robinson et al. (2012), Ruocco and Direkoglu (2013), Sauer et al. (2011a), Tipsord (2009); some papers contained more than one study.

74. Correlations averaged across studies, weighted for sample size. To make it easier to interpret these correlations, I use positive correlations for an effect in the expected direction. So a positive correlation between mindfulness and depressed mood means that more mindful people feel less depressed (i.e., better); a positive correlation with negative affect means that mindful people are in a better mood than less mindful people.

75. Daubenmier et al. (2014).

76. Hou et al. (2015).

77. Amutio et al. (2015), Anderson et al. (2007), Bao et al. (2015), Birnie et al. (2010), Chambers et al. (2005), Flook et al. (2013), Jain et al. (2007), Jensen et al. (2011), Lynch et al. (2011), Nyklíček and Kuipers (2008), Ortner et al. (2007), Teper and Inzlicht (2013), Wallmark et al. (2012).

78. Caveat: This is a very small number of studies, and for my conclusions to be valid, I need to make the assumption that researchers who didn't report these change correlations did so because they simply weren't thinking of doing this analysis, rather than not reporting the results because they found no effect.

79. To make it easier to interpret correlations, I use positive correlations for an effect in the expected direction. So a positive correlation between change in mindfulness and change in depressed mood means that people feel less depressed (i.e., better) with increases in mindfulness; a positive correlation with negative affect means that negative affect goes down (i.e., people are now in a better mood).

80. Average correlation, weighted for sample size.

81. Vøllestad et al. (2011). Note that this was a clinical sample of patients with anxiety disorder.

82. Baer et al. (2012).

83. Snippe et al. (2015).

84. Visted et al. (2014).

85. Zenner et al. (2014).

86. See Chapter 4 for an explanation on publication bias.

87. Effect included all outcome measures.

88. Shiba et al. (2015).

89. Shiba et al. (2015) do not provide any detail on the types of jobs these individuals held. All were employed, most had a college degree, and median household income was around $50,000 to $70,000.

90. I can recommend the movie documentary *Dhamma Brothers* to those interested in this aspect of mindfulness training.

91. Shonin et al. (2013).

92. The number of studies per outcome is too small to make a meta-analysis feasible.

93. de Vibe et al. (2015).

94. Mascaro et al. (2013b).

95. In this case, the anterior insula.

Chapter 7

1. For instance, Chiesa and Serretti (2010, 2011), Fjorback et al. (2011), Goyal et al. (2014), Grossman et al. (2004), Khoury et al. (2013a, 2013b), Klainin-Yobas et al. (2012), Piet and Hougaard (2011), Vøllestad et al. (2012).

2. Goyal et al. (2014).

3. In another meta-analysis, by Khoury and colleagues (2013a), which focused on mindfulness and did not exclude studies without a control group, 2,876 papers were retrieved; 31% of these were conceptual papers or reviews of other studies. It seems, then, that writers on mindfulness almost like to discuss meditation more than they are willing to actually study it. (And here I am, doing the same.)

4. To summarize the mantra meditation results (this included Transcendental Meditation® studies): Mantra meditation did not lead to significant effects on any of the mental health outcomes for either nonspecific or specific active control trials.

5. Meta-analysis by Fournier et al. (2010).

6. List of side effects of selective serotonin reuptake inhibitors and Xanax retrieved from webmd.com.

7. We will, however, consider some evidence for adverse effects of meditation later in this chapter.

8. Chiesa and Serretti (2011).

9. Ledesma and Kumano (2009).

10. Veehof et al. (2011).

11. Khoury et al. (2013b).

12. Piet and Hougaard (2011).

13. Khoury et al. (2013a).

14. Hofmann et al. (2010).

15. Santorelli (2014).

16. Khoury et al. (2013a).

17. Carmody and Baer (2009).

18. Vettese et al. (2009).

19. I assumed that the correlation in studies not showing a dose–response relationship was zero.

20. Gu et al. (2015), van der Velden et al. (2015).

21. Khoury et al. (2013a).

22. Hofmann et al. (2010).

23. Khoury et al. (2013a).

24. Supportive therapy is therapy in which the therapist acts as an emotional outlet, giving the patient the chance to express herself; it involves comforting, advising, encouraging, and active, empathic listening.

25. https://nccih.nih.gov/health/providers/digest/meditation-science.

26. This is not in the published paper—perhaps it was not deemed newsworthy—but it was reported in their long-form (439 pages!) report to the National Institute of Health; see http://www.ncbi.nlm.nih.gov/books/NBK180102/pdf/Bookshelf_NBK180102.pdf.

27. Kuijpers et al. (2007), Shapiro (1992), Yorston (2001).

28. Manocha (2000), Perez-de-Albeniz and Holmes (2000).

29. http://www.theatlantic.com/health/archive/2014/06/the-dark-knight-of-the-soul/372766/.

30. During her talk on this topic at the 2014 International Symposium for Contemplative Studies in Boston, Britton described these symptoms and asked the audience (by hand-raising) whether they thought this was part of the normal progress of meditation or something problematic. The large majority of the audience went for the first option. (Full

disclosure: I went for the second option, because anything that impairs you for months on end doesn't seem particularly liberating to me.)

31. Kerr et al. (2011).

32. Farias and Wikholm (2015).

Chapter 8

1. The dotted line covers only studies with healthy adults and placebo-controlled clinical samples, because it makes no sense to extend it to studies that directly compare mindfulness effects to those of standard treatment—the dotted line *is* the standard treatment.

2. With this caveat that there is variability in the results: some people become much better versions of themselves, others maybe less so, some do not change, and some might even become less happy.

3. For physiological effects of exercise, see http://www.cdc.gov/physicalactivity/basics/pa-health/; for effects on cognition, see Chang et al. (2012), Colcombe and Kramer (2003), Sibley and Etnier (2003).

4. Sixteen, not 17, because cortisol showed no effect.

5. There is one notable possible exception, and that is the effect on emotional stability, which goes in the opposite direction: Intervention studies show larger (and significant) effects compared to all studies. This suggests either that long-term meditators always were more neurotic than nonmeditators or that long-term meditation turned them more neurotic. The number of studies here is, however, small (two for interventions, two for existing differences), so we should be cautious about either conclusion.

6. The study used regression analysis, and so no correlations were reported.

7. For instance, Purser (2014) or Purser and Loy (2013).

8. Note that this is not a standard instruction for mindfulness meditation. It's also not necessarily the case that relaxation would be desirable at all times. Just try it out and see if it works for you.

9. All of these examples are from Williams and Penman (2011).

{ BIBLIOGRAPHY }

Aikens, K. A., Astin, J., Pelletier, K. R., Levanovich, K., Baase, C. M., Park, Y. Y., & Bodnar, C. M. (2014). Mindfulness goes to work: Impact of an online workplace intervention. *Journal of Occupational and Environmental Medicine*, *56*(7), 721–731.

Alexander, C. N., Langer, E. J., Newman, R. I., Chandler, H. M., & Davies, J. L. (1989). Transcendental meditation, mindfulness, and longevity: An experimental study with the elderly. *Journal of Personality and Social Psychology, 57*, 950–964.

Alidina, S., & Marshall, J. J. (2013). *Mindfulness workbook for dummies*. Chichester, UK: Wiley.

Allen, M., Dietz, M., Blair, K. S., van Beek, M., Rees, G., Vestergaard-Poulsen, P., . . . Roepstorff, A. (2012). Cognitive-affective neural plasticity following active-controlled mindfulness intervention. *The Journal of Neuroscience*, *32*, 15601–15610.

Amutio, A., Martínez-Taboada, C., Hermosilla, D., & Delgado, L. C. (2015). Enhancing relaxation states and positive emotions in physicians through a mindfulness training program: A one-year study. *Psychology, Health & Medicine*, *20*, 720–731.

Anderson, N. D., Lau, M. A., Segal, Z. V., & Bishop, S. R. (2007). Mindfulness-based stress reduction and attentional control. *Clinical Psychology & Psychotherapy, 14*, 449–463.

Anand, B., Chhina, G. S., & Singh, B. (1961). Some aspects of electroencephalographic studies in yogis. *Electroencephalography and Clinical Neurophysiology, 13*, 452–456.

Andrews-Hanna, J. R., Reidler, J. S., Sepulcre, J., Poulin, R., & Buckner, R. L. (2010). Functional-anatomic fractionation of the brain's default network. *Neuron*, *65*, 550–562.

Astin, J. A. (1997). Stress reduction through mindfulness meditation: Effects on psychological symptomatology, sense of control, and spiritual experiences. *Psychotherapy and Psychosomatics, 66*, 97–106.

Austin, J. H. (1999). *Zen and the brain: Towards an understanding of meditation and consciousness*. Cambridge, MA: MIT Press.

Austin, J. H. (2009). *Selfless insight*. Cambridge, MA: MIT Press.

Badawi, K., Wallace, R. K., Orme-Johnson, D., & Rouzere, A. M. (1984). Electrophysiologic characteristics of respiratory suspension periods occurring during the practice of the Transcendental Meditation Program. *Psychosomatic Medicine*, *46*, 267–276.

Baer, R. A. (2003). Mindfulness training as a clinical intervention: A conceptual and empirical review. *Clinical Psychology: Science and Practice*, 10, 125–143.

Baer, R. A., Lykins, E. L., & Peters, J. R. (2012). Mindfulness and self-compassion as predictors of psychological wellbeing in long-term meditators and matched nonmeditators. *The Journal of Positive Psychology*, *7*, 230–238.

Baer, R. A., Smith, G. T., & Allen, K. B. (2004). Assessment of mindfulness by self-report: The Kentucky inventory of mindfulness skills. *Assessment*, *11*, 191–206.

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13*, 27–45.

Bærentsen, K. B., Stødkilde-Jørgensen, H., Sommerlund, B., Hartmann, T., Damsgaard-Madsen, J., Fosnæs, M., & Green, A. C. (2010). An investigation of brain processes supporting meditation. *Cognitive Processing*, *11*, 57–84.

Banks, J. B., Welhaf, M. S., & Srour, A. (2015). The protective effects of brief mindfulness meditation training. *Consciousness and Cognition*, *33*, 277–285.

Banquet, J. P., & Sailhan, M. (1974). EEG analysis of spontaneous and induced states of consciousness. *Revue d'Electroencephalographie et de Neurophysiologie Clinique, 4*, 445–453.

Bao, X., Xue, S., & Kong, F. (2015). Dispositional mindfulness and perceived stress: The role of emotional intelligence. *Personality and Individual Differences*, *78*, 48–52.

Bar, M., Aminoff, E., Mason, M., & Fenske, M. (2007). The units of thought. *Hippocampus*, *17*, 420–428.

Baron Short, E., Kose, S., Mu, Q., Borckardt, J., Newberg, A., George, M. S., & Kozel, F. A. (2010). Regional brain activation during meditation shows time and practice effects: An exploratory fMRI study. *Evidence-Based Complementary and Alternative Medicine*, *7*, 121–127.

Barwood, T. J., Empson, J. A., Lister, S. G., & Tilley, A. J. (1978). Auditory evoked potentials and transcendental meditation. *Electroencephalography and Clinical Neurophysiology, 45*, 671–673.

Batson, C. D., Fultz, J., & Schoenrade, P. A. (1987). Distress and empathy: Two qualitatively distinct vicarious emotions with different motivational consequences. *Journal of Personality*, *55*, 19–39.

Beary, J. F., Benson, H., & Klemchuk, H. P. (1974). A simple psychophysiologic technique which elicits the hypometabolic changes of the relaxation response. *Psychosomatic Medicine*, *36*, 115–120.

Becker, D. E., & Shapiro, D. (1980). Directing attention toward stimuli affects the P300 but not the orienting response. *Psychophysiology, 17*, 385–389.

Benson, H., Lehmann, J. W., Malhotra, M. S., Goldman, R. F., Hopkins, J., & Epstein, M. D. (1982). Body temperature changes during the practice of g Tum-mo yoga. *Nature*, *295*, 234.

Benson, H., Malhotra, M. S., Goldman, R. F., Jacobs, G. D., & Hopkins, P. J. (1990). Three case reports of the metabolic and electroencephalographic changes during advanced Buddhist meditation techniques. *Behavioral Medicine*, *16*, 90–95.

Berkovich-Ohana, A., Dor-Ziderman, Y., Glicksohn, J., & Goldstein, A. (2013). Alterations in the sense of time, space, and body in the mindfulness-trained brain: A neurophenomenologically guided MEG study. *Frontiers in Psychology*, *4*.

Berkovich-Ohana, A., Glicksohn, J., & Goldstein, A. (2011). Temporal cognition changes following mindfulness, but not transcendental meditation practice. *Proceedings of Fechner Day*, *27*(1), 245–250.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993). Respiratory sinus arrhythmia: Autonomic origins, physiological mechanisms, and psychophysiological implications. *Psychophysiology*, *30*, 183–196.

Birnie, K., Speca, M., & Carlson, L. E. (2010). Exploring self-compassion and empathy in the context of mindfulness-based stress reduction (MBSR). *Stress and Health*, *26*, 359–371.

Black, D. S., Semple, R. J., Pokhrel, P., & Grenard, J. L. (2011). Component processes of executive function—Mindfulness, self-control, and working memory—and their relationships with mental and behavioral health. *Mindfulness*, *2*, 179–185.

Blanke, O., Mohr, C., Michel, C. M., Pascual-Leone, A., Brugger, P., Seeck, M., . . . Thut, G. (2005). Linking out-of-body experience and self processing to mental own-body imagery at the temporoparietal junction. *The Journal of Neuroscience*, *25*, 550–557.

Bögels, S., Hoogstad, B., van Dun, L., de Schutter, S., & Restifo, K. (2008). Mindfulness training for adolescents with externalizing disorders and their parents. *Behavioural and Cognitive Psychotherapy*, *36*, 193–209.

Bornemann, B., Herbert, B. M., Mehling, W. E., & Singer, T. (2014). Differential changes in self-reported aspects of interoceptive awareness through 3 months of contemplative training. *Frontiers in Psychology*, *5*.

Boroojerdi, B., Battaglia, F., Muellbacher, W., & Cohen, L. G. (2001). Mechanisms underlying rapid experience-dependent plasticity in the human visual cortex. *Proceedings of the National Academy of Sciences*, *98*, 14698–14701.

Braboszcz, C., Habnusseau, S., & Delorme, A. (2010). Meditation and neuroscience: From basic research to clinical practice. In R. Carlstedt (Ed.), *Integrating psychology, psychiatry, and behavioral medicine. Perspectives, practices, and research* (pp. 1910–1929). New York: Springer.

Brahm, A. (2006). *Happiness through meditation*. Boston: Wisdom.

Brasington, L. (2015). *Right concentration: A practical guide to the jhānas*. Boston: Shambhala.

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences*, *104*, 11483–11488.

Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: Emerging methods and principles. *Trends in Cognitive Sciences*, *14*, 277–290.

Brewer, J. A., Worhunsky, P. D., Gray, J. R., Tang, Y. Y., Weber, J., & Kober, H. (2011). Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences*, *108*, 20254–20259.

Britton, W. B., Haynes, P. L., Fridel, K. W., & Bootzin, R. R. (2010). Polysomnographic and subjective profiles of sleep continuity before and after mindfulness-based cognitive therapy in partially remitted depression. *Psychosomatic Medicine*, *72*, 539–548.

Britton, W. B., Lindahl, J. R., Cahn, B. R., Davis, J. H., & Goldman, R. E. (2014). Awakening is not a metaphor: The effects of Buddhist meditation practices on basic wakefulness. *Annals of the New York Academy of Sciences*, *1307*, 64–81.

Broks, P. (2003). *Into the silent land: Travels in neuropsychology*. London: Atlantic.

Brotto, L. A., & Basson, R. (2014). Group mindfulness-based therapy significantly improves sexual desire in women. *Behaviour Research and Therapy*, *57*, 43–54.

Brotto, L. A., Basson, R., Carlson, M., & Zhu, C. (2013). Impact of an integrated mindfulness and cognitive behavioural treatment for provoked vestibulodynia (IMPROVED): A qualitative study. *Sexual and Relationship Therapy*, *28*, 3–19.

Brotto, L. A., Basson, R., Smith, K. B., Driscoll, M., & Sadownik, L. (2014). Mindfulness-based group therapy for women with provoked vestibulodynia. *Mindfulness*, *6*, 417–432.

Brotto, L. A., Erskine, Y., Carey, M., Ehlen, T., Finlayson, S., Heywood, M., . . . Miller, D. (2012a). A brief mindfulness-based cognitive behavioral intervention improves sexual functioning versus wait-list control in women treated for gynecologic cancer. *Gynecologic Oncology*, *125*, 320–325.

Brotto, L. A., & Heiman, J. R. (2007). Mindfulness in sex therapy: Applications for women with sexual difficulties following gynecologic cancer. *Sexual and Relationship Therapy*, *22*, 3–11.

Brotto, L. A., Heiman, J. R., Goff, B., Greer, B., Lentz, G. M., Swisher, E., . . . Van Blaricom, A. (2008). A psychoeducational intervention for sexual dysfunction in women with gynecologic cancer. *Archives of Sexual Behavior*, *37*, 317–329.

Brotto, L. A., Seal, B. N., & Rellini, A. (2012b). Pilot study of a brief cognitive behavioral versus mindfulness-based intervention for women with sexual distress and a history of childhood sexual abuse. *Journal of Sex & Marital Therapy*, *38*, 1–27.

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*, 822–848.

Brown, K. W., Ryan, R. M., & Creswell, J. D. (2007). Mindfulness: Theoretical foundations and evidence for its salutary effects. *Psychological Inquiry*, *18*, 211–237.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network. *Annals of the New York Academy of Sciences*, *1124*, 1–38.

Burgess, P. W., Dumontheil, I., & Gilbert, S. J. (2007). The gateway hypothesis of rostral prefrontal cortex (area 10) function. *Trends in Cognitive Sciences*, *11*, 290–298.

Cahn, B. R., Delorme, A., & Polich, J. (2010). Occipital gamma activation during Vipassana meditation. *Cognitive Processing*, *11*, 39–56.

Cahn, B. R., Delorme, A., & Polich, J. (2013). Event-related delta, theta, alpha and gamma correlates to auditory oddball processing during Vipassana meditation. *Social Cognitive & Affective Neuroscience*, *8*, 100–111.

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, *132*, 180–211.

Carboni, J. A., Roach, A. T., & Fredrick, L. D. (2013). Impact of mindfulness training on the behavior of elementary students with attention-deficit/hyperactive disorder. *Research in Human Development*, *10*, 234–251.

Carmody, J., & Baer, R. A. (2009). How long does a mindfulness-based stress reduction program need to be? A review of class contact hours and effect sizes for psychological distress. *Journal of Clinical Psychology*, *65*, 627–638.

Carson, J. W., Carson, K. M., Gil, K. M., & Baucom, D. H. (2004). Mindfulness-based relationship enhancement. *Behavior Therapy, 35*, 471–494.

Carter, O. L., Presti, D. E., Callistemon, C., Ungerer, Y., Liu, G. B., & Pettigrew, J. D. (2005). Meditation alters perceptual rivalry in Tibetan Buddhist monks. *Current Biology*, *15*, R412–R413.

Catherine, S. (2008). *Focused and fearless: A meditator's guide to states of deep joy, calm and clarity.* Boston: Wisdom.

Chaddock-Heyman, L., Erickson, K. I., Voss, M. W., Powers, J. P., Knecht, A. M., Pontifex, M. B., . . . Hillman, C. H. (2013). White matter microstructure is associated with cognitive control in children. *Biological Psychology*, *94*, 109–115.

Chambers, R., Lo, B. C. Y., & Allen, N. B. (2008). The impact of intensive mindfulness training on attentional control, cognitive style, and affect. *Cognitive Therapy and Research*, *32*, 303–322.

Chan, D., & Woollacott, M. (2007). Effects of level of meditation experience on attentional focus: Is the efficiency of executive or orientation networks improved? *The Journal of Alternative and Complementary Medicine, 13*, 651–658.

Chang, C. H., & Lo, P. C. (2013). Effects of long-term dharma-chan meditation on cardiorespiratory synchronization and heart rate variability behavior. *Rejuvenation Research, 16*, 115–123.

Chang, V. Y., Palesh, O., Caldwell, R., Glasgow, N., Abramson, M., Luskin, F., Koopman, C. (2004). The effects of a mindfulness-based stress reduction program on stress, mindfulness self-efficacy, and positive states of mind. *Stress and Health: Journal of the International Society for the Investigation of Stress, 20*, 141–147.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research*, *1453*, 87–101.

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical Psychology Review*, *31*(3), 449–464.

Chiesa, A., & Malinowski, P. (2011). Mindfulness-based approaches: Are they all the same? *Journal of Clinical Psychology*, *67*, 404–424.

Chiesa, A., & Serretti, A. (2009). Mindfulness-based stress reduction for stress management in healthy people: A review and meta-analysis. *The Journal of Alternative and Complementary Medicine*, *15*, 593–600.

Chiesa, A., & Serretti, A. (2010). A systematic review of neurobiological and clinical features of mindfulness meditations. *Psychological Medicine*, *40*, 1239–1252.

Chiesa, A., & Serretti, A. (2011). Mindfulness based cognitive therapy for psychiatric disorders: a systematic review and meta-analysis. *Psychiatry Research*, *187*, 441–453.

Chiesa, A., Serretti, A., & Jakobsen, J. C. (2013). Mindfulness: Top-down or bottom-up emotion regulation strategy? *Clinical Psychology Review*, *33*, 82–96.

Chu, L. (2010). The benefits of meditation vis-à-vis emotional intelligence, perceived stress and negative mental health. *Stress and Health: Journal of the International Society for the Investigation of Stress, 26*, 169–180.

Clarke, T. C., Black, L. I., Stussman, B. J., Barnes, P. M., & Nahin, R. L. (2015). Trends in the use of complementary health approaches among adults: United States, 2002–2012. *National Health Statistics Reports*, *79*, 1–16.

Coffey, K. A., Hartman, M., & Fredrickson, B. L. (2010). Deconstructing mindfulness and constructing mental health: Understanding mindfulness and its mechanisms of action. *Mindfulness*, *1*, 235–253.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science*, *14*, 125–130.

Cole, J., Chaddock, C. A., Farmer, A. E., Aitchison, K. J., Simmons, A., McGuffin, P., & Fu, C. H. (2012). White matter abnormalities and illness severity in major depressive disorder. *The British Journal of Psychiatry*, *201*, 33–39.

Conrad, C. D. (2008). Chronic stress-induced hippocampal vulnerability: The glucocorticoid vulnerability hypothesis. *Reviews in the Neurosciences*, *19*, 395–412.

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron*, *58*, 306–324.

Craig, A. D. (2005). Forebrain emotional asymmetry: A neuroanatomical basis? *Trends in Cognitive Sciences*, *9*, 566–571.

Creswell, J. D., & Lindsay, E. K. (2014). How does mindfulness training affect health? A mindfulness stress buffering account. *Current Directions in Psychological Science*, *23*, 401–407.

Creswell, J. D., Myers, H. F., Cole, S. W., & Irwin, M. R. (2009). Mindfulness meditation training effects on CD4+ T lymphocytes in HIV-1 infected adults: A small randomized controlled trial. *Brain, Behavior, and Immunity*, *23*, 184–188.

Cysarz, D., & Büssing, A. (2005). Cardiorespiratory synchronization during Zen meditation. *European Journal of Applied Physiology*, *95*, 88–95.

Dalai Lama (2005). *The universe in a single atom: The convergence of science and spirituality*. New York: Morgan Road.

Damasio, A. (2010). *Self comes to mind*. New York: Pantheon.

Daubenmier, J., Hayden, D., Chang, V., & Epel, E. (2014). It's not what you think, it's how you relate to it: Dispositional mindfulness moderates the relationship between psychological distress and the cortisol awakening response. *Psychoneuroendocrinology*, *48*, 11–18.

Daubenmier, J., Sze, J., Kerr, C. E., Kemeny, M. E., & Mehling, W. (2013). Follow your breath: Respiratory interoceptive accuracy in experienced meditators. *Psychophysiology*, *50*, 777–789.

David-Néel, A. (1929). *Mystiques et magiciens du Tibet*. Paris: Plon.

Davidson, R. J., Kabat-Zinn, J., Schumacher, J., Rosenkranz, M., Muller, D., Santorelli, S. F., . . . Sheridan, J. F. (2003). Alterations in brain and immune function produced by mindfulness meditation. *Psychosomatic Medicine*, *65*, 564–570.

Davidson, R. J., Pizzagalli, D., Nitschke, J. B., & Putnam, K. (2002). Depression: Perspectives from affective neuroscience. *Annual Review of Psychology*, *53*, 545–574.

Decety, J., & Lamm, C. (2007). The role of the right temporoparietal junction in social interaction: How low-level computational processes contribute to meta-cognition. *The Neuroscientist*, *13*, 580–593.

de Grâce, G. (1976). Effects of meditation on personality and values. *Journal of Clinical Psychology*, *32*(4), 809–813.

Dennett. D. C. (1991). *Consciousness explained*. London: Penguin.

Desbordes, G., Negi, L. T., Pace, T. W., Wallace, B. A., Raison, C. L., & Schwartz, E. L. (2012). Effects of mindful-attention and compassion meditation training on amygdala response to emotional stimuli in an ordinary, non-meditative state. *Frontiers in Human Neuroscience*, *6*.

Deshmukh, V. D. (2006). Neuroscience of meditation. *The Scientific World Journal*, *6*, 2239–2253.

de Vibe, M., Solhaug, I., Tyssen, R., Friborg, O., Rosenvinge, J. H., Sørlie, T., & Bjørndal, A. (2013). Mindfulness training for stress management: A randomised controlled study of medical and psychology students. *BMC Medical Education*, *13*, 107.

de Vibe, M., Solhaug, I., Tyssen, R., Friborg, O., Rosenvinge, J. H., Sørlie, T., . . . Bjørndal, A. (2015). Does personality moderate the effects of mindfulness training for medical and psychology students? *Mindfulness*, *6*, 281–289.

Dor-Ziderman, Y., Berkovich-Ohana, A., Glicksohn, J., & Goldstein, A. (2013). Mindfulness-induced selflessness: A MEG neurophenomenological study. *Frontiers in Human Neuroscience*, *7*.

Dove, N. L., & Wiederman, M. W. (2000). Cognitive distraction and women's sexual functioning. *Journal of Sex & Marital Therapy*, *26*, 67–78.

Draganski, B., Gaser, C., Busch, V., Schuierer, G., Bogdahn, U., & May, A. (2004). Neuroplasticity: Changes in grey matter induced by training. *Nature*, *427*, 311–312.

Droit-Volet, S., Fanget, M., & Dambrun, M. (2015). Mindfulness meditation and relaxation training increases time sensitivity. *Consciousness and Cognition*, *31*, 86–97.

Eberth, J., & Sedlmeier, P. (2012). The effects of mindfulness meditation: A meta-analysis. *Mindfulness*, *3*, 174–189.

Eisenberg, N., Fabes, R. A., Miller, P. A., Fultz, J., Shell, R., Mathy, R. M., & Reno, R. R. (1989). Relation of sympathy and personal distress to prosocial behavior: A multimethod study. *Journal of Personality and Social Psychology*, *57*, 55–66.

Engström, M., & Söderfeldt, B. (2010). Brain activation during compassion meditation: A case study. *The Journal of Alternative and Complementary Medicine*, *16*, 597–599.

Esslen, M., Metzler, S., Pascual-Marqui, R., & Jancke, L. (2008). Pre-reflective and reflective self-reference: A spatiotemporal EEG analysis. *NeuroImage*, *42*, 437–449.

Evans, D. R., & Segerstrom, S. C. (2011). Why do mindful people worry less? *Cognitive Therapy and Research*, *35*, 505–510.

Fan, Y., Duncan, N. W., de Greck, M., & Northoff, G. 2011. Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neuroscience & Biobehavioral Reviews, 35*, 903–911.

Farb, N. A., Segal, Z. V., & Anderson, A. K. (2013). Mindfulness meditation training alters cortical representations of interoceptive attention. *Social Cognitive & Affective Neuroscience*, *8*, 15–26.

Farb, N. A., Segal, Z. V., Mayberg, H., Bean, J., McKeon, D., Fatima, Z., & Anderson, A. K. (2007). Attending to the present: Mindfulness meditation reveals distinct neural modes of self-reference. *Social Cognitive & Affective Neuroscience*, *2*, 313–322.

Farias, M., & Wikholm, C. (2015). *The Buddha pill: Can meditation change you?* London: Watkins.

Fenwick, P. B. C., Donaldson, S., Gillis, L., Bushman, J., Fenton, G. W., Perry, I., ... Serafinowicz, H. (1977). Metabolic and EEG changes during transcendental meditation: An explanation. *Biological Psychology*, *5*, 101–118.

Ferrarelli, F., Smith, R., Dentico, D., Riedner, B. A., Zennig, C., Benca, R. M., ... Tononi, G. (2013). Experienced mindfulness meditators exhibit higher parietal-occipital EEG gamma activity during NREM sleep. *PloS One*, *8*, e73417.

ffytche, D. H., Howard, R. J., Brammer, M. J., David, A., Woodruff, P., & Williams, S. (1998). The anatomy of conscious vision: An fMRI study of visual hallucinations. *Nature Neuroscience*, *1*, 738–742.

Fischer, N. (2013). *Training in compassion: Zen teachings on the practice of lojong*. Boston: Shambhala.

Fjorback, L. O., Arendt, M., Ørnbøl, E., Fink, P., & Walach, H. (2011). Mindfulness-based stress reduction and mindfulness-based cognitive therapy: A systematic review of randomized controlled trials. *Acta Psychiatrica Scandinavica*, *124*, 102–119.

Fleming, A. P., McMahon, R. J., Moran, L. R., Peterson, A. P., & Dreessen, A. (2015). Pilot randomized controlled trial of dialectical behavior therapy group skills training for ADHD among college students. *Journal of Attention Disorders*, *19*, 260–271.

Flook, L., Goldberg, S. B., Pinger, L., Bonus, K., & Davidson, R. J. (2013). Mindfulness for teachers: A pilot study to assess effects on stress, burnout, and teaching efficacy. *Mind, Brain, and Education*, *7*, 182–195.

Fossati, P., Hevenor, S. J., Graham, S. J., Grady, C., Keightley, M. L., Craik, F., & Mayberg, H. (2003). In search of the emotional self: An fMRI study using positive and negative emotional words. *The American Journal of Psychiatry*, *160*, 1938–1945.

Fournier, J. C., DeRubeis, R. J., Hollon, S. D., Dimidjian, S., Amsterdam, J. D., Shelton, R. C., & Fawcett, J. (2010). Antidepressant drug effects and depression severity: A patient-level meta-analysis. *JAMA: The Journal of the American Medical Association*, *303*, 47–53.

Fox, K. C., Dixon, M. L., Nijeboer, S., Girn, M., Floman, J. L., Lifshitz, M., . . . Christoff, K. (2016). Functional neuroanatomy of meditation: A review and meta-analysis of 78 functional neuroimaging investigations. *Neuroscience & Biobehavioral Reviews*, *65*, 208–228.

Fox, K. C., Nijeboer, S., Dixon, M. L., Floman, J. L., Ellamil, M., Rumak, S. P., . . . Christoff, K. (2014). Is meditation associated with altered brain structure? A systematic review and meta-analysis of morphometric neuroimaging in meditation practitioners. *Neuroscience & Biobehavioral Reviews*, *43*, 48–73.

Fox, K. C., Zakarauskas, P., Dixon, M., Ellamil, M., Thompson, E., & Christoff, K. (2012). Meditation experience predicts introspective accuracy. *PLoS One, 7*, e45370.

Fredrickson, B. L., Cohn, M. A., Coffey, K. A., Pek, J., & Finkel, S. M. (2008). Open hearts build lives: Positive emotions, induced through loving-kindness meditation, build consequential personal resources. *Journal of Personality and Social Psychology*, *95*, 1045–1065.

Froeliger, B., Garland, E. L., & McClernon, F. J. (2012). Yoga meditation practitioners exhibit greater gray matter volume and fewer reported cognitive failures: Results of a preliminary voxel-based morphometric analysis. *Evidence-Based Complementary and Alternative Medicine*, *2012*.

Gallagher, S. (2000). Philosophical conceptions of the self. *Trends in Cognitive Sciences 4*, 14–21.

Gallego, J., Aguilar-Parra, J. M., Cangas, A. J., Langer, Á. I., & Mañas, I. (2014). Effect of a mindfulness program on stress, anxiety and depression in university students. *The Spanish Journal of Psychology*, *17*, 1–6.

Gallois, P. (1984). Modifications neurophysiologiques et respiratoires Iors de la pratique des techniques de relaxation. *L'Encephale, 10*, 139–144.

Gard, T., Hölzel, B. K., Sack, A. T., Hempel, H., Lazar, S. W., Vaitl, D., & Ott, U. (2012). Pain attenuation through mindfulness is associated with decreased cognitive control and increased sensory processing in the brain. *Cerebral Cortex*, *22*, 2692–2702.

Garland, E. L., Beck, A. C., Lipschitz, D. L., & Nakamura, Y. (2015). Dispositional mindfulness predicts attenuated waking salivary cortisol levels in cancer survivors: A latent growth curve analysis. *Journal of Cancer Survivorship, 9*, 1–8.

Garrison, K. A., Santoyo, J. F., Davis, J. H., Thornhill IV, T. A., Kerr, C. E., & Brewer, J. A. (2013). Effortless awareness: Using real time neurofeedback to investigate correlates of posterior cingulate cortex activity in meditators' self-report. *Frontiers in Human Neuroscience*, *7*.

Garrison, K. A., Scheinost, D., Constable, R. T., & Brewer, J. A. (2014). BOLD signal and functional connectivity associated with loving kindness meditation. *Brain and Behavior*, *4*, 337–347.

Gauthier, T., Meyer, R. M., Grefe, D., & Gold, J. I. (2015). An on-the-job mindfulness-based intervention for pediatric ICU nurses: A pilot. *Journal of Pediatric Nursing*, *30*, 402–409.

Gazzaniga, M. S. (1998). The split brain revisited. *Scientific American*, *279*, 50–55.

Geary, C., & Rosenthal, S. L. (2011). Sustained impact of MBSR on stress, well-being, and daily spiritual experiences for 1 year in academic health care employees. *The Journal of Alternative and Complementary Medicine*, *17*, 939–944.

Glicksohn, J. (2001). Temporal cognition and the phenomenology of time: A multiplicative function for apparent duration. *Consciousness and Cognition*, *10*, 1–25.

Goldin, P. R., & Gross, J. J. (2010). Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. *Emotion*, *10*, 83–91.

Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: Reappraisal and suppression of negative emotion. *Biological Psychiatry*, *63*, 577–586.

Goldstein, J. (2013). *Mindfulness: A practical guide to awakening*. Boulder, CO: Sounds True.

Goleman, D. (1996). *The meditative mind: The varieties of meditative experience*. Los Angelos: Tarcher Perigree.

Goyal, M., Singh, S., Sibinga, E. M., Gould, N. F., Rowland-Seymour, A., Sharma, R., . . . Haythornthwaite, J. A. (2014). Meditation programs for psychological stress and well-being: A systematic review and meta-analysis. *JAMA Internal Medicine*, *174*, 357–368.

Grabovac, A. D., Lau, M. A., & Willett, B. R. (2011). Mechanisms of mindfulness: A Buddhist psychological model. *Mindfulness*, *2*, 154–166.

Grant, J. A. (2014). Meditative analgesia: The current state of the field. *Annals of the New York Academy of Sciences*, *1307*, 55–63.

Grant, J., Courtemanche, J., Duerden, E. G., Duncan, G. H., & Rainville, P. (2010). Cortical thickness and pain sensitivity in Zen meditators. *Emotion*, *10*, 43–53.

Grant, J. A., & Rainville, P. (2009). Pain sensitivity and analgesic effects of mindful states in Zen meditators: A cross-sectional study. *Psychosomatic Medicine*, *71*, 106–114.

Greene, Y. N., & Hiebert, B. (1988). A comparison of mindfulness meditation and cognitive self-observation. *Canadian Journal of Counselling, 22*, 25–34.

Gregório, S., & Pinto-Gouveia, J. (2013). Mindful attention and awareness: Relationships with psychopathology and emotion regulation. *The Spanish Journal of Psychology*, *16*, 1–10.

Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits: A meta-analysis. *Journal of Psychosomatic Research*, *57*, 35–43.

Grossman, P., & Van Dam, N. T. (2011). Mindfulness, by any other name . . .: Trials and tribulations of sati in Western psychology and science. *Contemporary Buddhism*, *12*, 219–239.

Gu, J., Strauss, C., Bond, R., & Cavanagh, K. (2015). How do mindfulness-based cognitive therapy and mindfulness-based stress reduction improve mental health and wellbeing? A systematic review and meta-analysis of mediation studies. *Clinical Psychology Review*, *37*, 1–12.

Gyatso, K. N. (2004). *Ornament of stainless light: An exposition of the kālacakra tantra.* Edited and translated by G. Kilty. Boston: Wisdom.

Hagerty, M. R., Isaacs, J., Brasington, L., Shupe, L., Fetz, E. E., & Cramer, S. C. (2013). Case study of ecstatic meditation: fMRI and EEG evidence of self-stimulating a reward system. *Neural Plasticity*, *2013*, 653572.

Haggard, P., & Whitford, B. (2004). Supplementary motor area provides an efferent signal for sensory suppression. *Cognitive Brain Research*, *19*, 52–58.

Hasenkamp, W., & Barsalou, L. W. (2012). Effects of meditation experience on functional connectivity of distributed brain networks. *Frontiers in Human Neuroscience*, *6*.

Hasenkamp, W., Wilson-Mendenhall, C. D., Duncan, E., & Barsalou, L. W. (2012). Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *NeuroImage*, *59*, 750–760.

Haver, A., Akerjordet, K., Caputi, P., Furunes, T., & Magee, C. (2015). Measuring mental well-being: A validation of the Short Warwick–Edinburgh Mental Well-Being Scale in Norwegian and Swedish. *Scandinavian Journal of Public Health*, *43*, 721–727.

Haydicky, J., Shecter, C., Wiener, J., & Ducharme, J. M. (2015). Evaluation of MBCT for adolescents with ADHD and their parents: Impact on individual and family functioning. *Journal of Child and Family Studies*, *24*, 76–94.

Hayes, S. C., Strosahl, K. D., & Wilson, K. G. (1999). *Acceptance and commitment therapy: An experiential approach to behavior change*. New York: Guilford.

Heeren, A., Van Broeck, N., & Philippot, P. (2009). The effects of mindfulness on executive processes and autobiographical memory specificity. *Behaviour Research and Therapy*, *47*, 403–409.

Hepark, S., Kan, C. C., & Speckens, A. (2014). [Feasibility and effectiveness of mindfulness training in adults with ADHD: A pilot study]. *Tijdschrift voor Psychiatrie*, *56*, 471–476.

Herman, J. P., & Mueller, N. K. (2006). Role of the ventral subiculum in stress integration. *Behavioural Brain Research*, *174*, 215–224.

Hirvikoski, T., Waaler, E., Alfredsson, J., Pihlgren, C., Holmström, A., Johnson, A., . . . Nordström, A. L. (2011). Reduced ADHD symptoms in adults with ADHD after structured skills training group: Results from a randomized controlled trial. *Behaviour Research and Therapy*, *49*, 175–185.

Hodgins, H. S., & Adair, K. C. (2010). Attentional processes and meditation. *Consciousness and Cognition*, *19*, 872–878.

Hofmann, S. G., Sawyer, A. T., Witt, A. A., & Oh, D. (2010). The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *Journal of Consulting and Clinical Psychology*, *78*, 169–183.

Hölzel, B. K., Carmody, J., Evans, K. C., Hoge, E. A., Dusek, J. A., Morgan, L., . . . Lazar, S. W. (2010). Stress reduction correlates with structural changes in the amygdala. *Social Cognitive & Affective Neuroscience*, *5*, 11–17.

Hölzel, B. K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S. M., Gard, T., & Lazar, S. W. (2011a). Mindfulness practice leads to increases in regional brain gray matter density. *Psychiatry Research: Neuroimaging*, *191*(1), 36–43.

Hölzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011b). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science*, *6*, 537–559.

Hou, W. K., Ng, S. M., & Wan, J. H. Y. (2015). Changes in positive affect and mindfulness predict changes in cortisol response and psychiatric symptoms: A latent change score modelling approach. *Psychology & Health*, *30*, 551–567.

Hucker, A., & McCabe, M. P. (2014). A qualitative evaluation of online chat groups for women completing a psychological intervention for female sexual dysfunction. *Journal of Sex & Marital Therapy*, *40*, 58–68.

Hutton, C., Draganski, B., Ashburner, J., Weiskopf, N., 2009. A comparison between voxel-based cortical thickness and voxel-based morphometry in normal aging. *NeuroImage, 48*, 371–380.

Jacobs, T. L., Epel, E. S., Lin, J., Blackburn, E. H., Wolkowitz, O. M., Bridwell, D. A., . . . King, B. G. (2011). Intensive meditation training, immune cell telomerase activity, and psychological mediators. *Psychoneuroendocrinology*, *36*, 664–681.

Jain, S., Shapiro, S. L., Swanick, S., Roesch, S. C., Mills, P. J., Bell, I., & Schwartz, G. E. (2007). A randomized controlled trial of mindfulness meditation versus relaxation training: Effects on distress, positive states of mind, rumination, and distraction. *Annals of Behavioral Medicine*, *33*, 11–21.

Jazaieri, H., Jinpa, G. T., McGonigal, K., Rosenberg, E. L., Finkelstein, J., Simon-Thomas, E., . . . Goldin, P. R. (2013). Enhancing compassion: A randomized controlled trial of a compassion cultivation training program. *Journal of Happiness Studies*, *14*, 1113–1126.

Jensen, C., Vangkilde, S., Frokjaer, V., & Hasselbalch, S. G. (2011). Mindfulness training affects attention—or is it attentional effort? *Journal of Experimental Psychology: General, 141*, 106–123.

Jerath, R., Barnes, V. A., Dillard-Wright, D., Jerath, S., & Hamilton, B. (2012). Dynamic change of awareness during meditation techniques: Neural and physiological correlates. *Frontiers in Human Neuroscience*, *6*.

Jovanov, E. (2005). On spectral analysis of heart rate variability during very slow yogic breathing. *Conference Proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, *3*, 2467–2470.

Jevning, R., Wallace, R. K., & Beidebach, M. (1992). The physiology of meditation: A review. A wakeful hypometabolic integrated response. *Neuroscience & Biobehavioral Reviews*, *16*, 415–424.

Jha, A. P., Krompinger, J., & Baime, M. J. (2007). Mindfulness training modifies subsystems of attention. *Cognitive, Affective & Behavioral Neuroscience*, *7*, 109–119.

Jha, A. P., Morrison, A. B., Dainer-Best, J., Parker, S., Rostrup, N., & Stanley, E. A. (2015). Minds "at attention": Mindfulness training curbs attentional lapses in military cohorts. *PloS One*, *10*, e0116889.

Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion*, *10*, 54–64.

Josipovic, Z., Dinstein, I., Weber, J., & Heeger, D. J. (2012). Influence of meditation on anti-correlated networks in the brain. *Frontiers in Human Neuroscience*, *5*.

Kabat-Zinn, J. (1990). *Full catastrophe living: The program of the stress reduction clinic at the University of Massachusetts Medical Center*. New York: Delta.

Kabat-Zinn, J. (1994). *Wherever you go, there you are: Mindfulness meditation in everyday life*. New York: Hyperion.

Kabat-Zinn, J. (1998). Toward the mainstreaming of American Dharma practice. In A. Rapaport & B. D. Hotchkiss (Eds.), *Buddhism in America: The official record of the landmark conference on the future of Buddhist meditative practices in the West, Boston, January 17–19, 1997* (pp. 478–528). Rutland, VT: Tuttle.

Kabat-Zinn, J. (2005). *Coming to our senses: Healing ourselves and the world through mindfulness*. London: Hachette.

Kabat-Zinn, J. (2011). Some reflections on the origins of MBSR, skillful means, and the trouble with maps. *Contemporary Buddhism*, *12*, 281–306.

Kakigi, R., Nakata, H., Inui, K., Hiroe, N., Nagata, O., Honda, M., . . . Kawakami, M. (2005). Intracerebral pain processing in a yoga master who claims not to feel pain during meditation. *European Journal of Pain*, *9*, 581–581.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *The Journal of Neuroscience*, *17*, 4302–4311.

Kasamatsu, A., & Hirai, T. (1966). An electroencephalographic study on the Zen meditation (Zazen). *Folia Psychiatrica et Neurologica Japonica, 20*, 315–336.

Kaul, P., Passafiume, J., Sargent, C. R., & O'Hara, B. F. (2010). Meditation acutely improves psychomotor vigilance, and may decrease sleep need. *Behavioral and Brain Functions*, *6*, 47–47.

Keltner, D., & Goetz, J. L. (2007). Compassion. In R. F. Baumeister & K. D. Vohs (Eds.), *Encyclopedia of social psychology* (pp. 159–161). Thousand Oaks, CA: SAGE.

Kemper, K. J., Lynn, J., & Mahan, J. D. (2015). What is the impact of online training in mind-body skills? *Journal of Evidence-Based Complementary & Alternative Medicine, 20*, 275–282.

Kerr, C. E., Jones, S. R., Wan, Q., Pritchett, D. L., Wasserman, R. H., Wexler, A., . . . Moore, C. I. (2011). Effects of mindfulness meditation training on anticipatory alpha modulation in primary somatosensory cortex. *Brain Research Bulletin*, *85*, 96–103.

Khalsa, S. S., Rudrauf, D., Damasio, A. R., Davidson, R. J., Lutz, A., & Tranel, D. (2008). Interoceptive awareness in experienced meditators. *Psychophysiology*, *45*, 671–677.

Khoury, B., Lecomte, T., Fortin, G., Masse, M., Therien, P., Bouchard, V., . . . Hofmann, S. G. (2013a). Mindfulness-based therapy: A comprehensive meta-analysis. *Clinical Psychology Review*, *33*, 763–771.

Khoury, B., Lecomte, T., Gaudiano, B. A., & Paquin, K. (2013b). Mindfulness interventions for psychosis: A meta-analysis. *Schizophrenia Research*, *150*, 176–184.

Kieseppä, T., Eerola, M., Mäntylä, R., Neuvonen, T., Poutanen, V. P., Luoma, K., . . . Rytsälä, H. (2010). Major depressive disorder and white matter abnormalities: A diffusion tensor imaging study with tract-based spatial statistics. *Journal of Affective Disorders*, *120*, 240–244.

Kiken, L. G., Garland, E. L., Bluth, K., Palsson, O. S., & Gaylord, S. A. (2015). From a state to a trait: Trajectories of state mindfulness in meditation during intervention predict changes in trait mindfulness. *Personality and Individual Differences*, *81*, 41–46.

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science*, *330*, 932–932.

Kim, K., & Johnson, M. K. (2014). Extended self: spontaneous activation of medial prefrontal cortex by objects that are "mine." *Social Cognitive & Affective Neuroscience*, *9*, 1006–1012.

Kircher, T. T., Brammer, M., Bullmore, E., Simmons, A., Bartels, M., & David, A. S. (2002). The neural correlates of intentional and incidental self processing. *Neuropsychologia*, *40*, 683–692.

Kirsch, I., Deacon, B. J., Huedo-Medina, T. B., Scoboria, A., Moore, T. J., & Johnson, B. T. (2008). Initial severity and antidepressant benefits: A meta-analysis of data submitted to the Food and Drug Administration. *PLoS Medicine*, *5*.

Kirsch, I., & Henry, D. (1979). Self-desensitization and meditation in the reduction of public speaking anxiety. *Journal of Consulting and Clinical Psychology, 47*, 536–541.

Kitney, R. I., & Rompelman, O. (1980). *The study of heart-rate variability*. New York: Oxford University Press.

Kjaer, T. W., Nowak, M., & Lou, H. C. (2002). Reflective self-awareness and conscious states: PET evidence for a common midline parietofrontal core. *NeuroImage*, *17*, 1080–1086.

Klainin-Yobas, P., Cho, M. A. A., & Creedy, D. (2012). Efficacy of mindfulness-based interventions on depressive symptoms among people with mental disorders: A meta-analysis. *International Journal of Nursing Studies*, *49*, 109–121.

Klatt, M. D., Buckworth, J., & Malarkey, W. B. (2009). Effects of low-dose mindfulness-based stress reduction (MBSR-ld) on working adults. *Health Education & Behavior, 36*, 601–614.

Klimecki, O. M., Leiberg, S., Lamm, C., & Singer, T. (2013a). Functional neural plasticity and associated changes in positive affect after compassion training. *Cerebral Cortex*, *23*, 1552–1561.

Klimecki, O. M., Leiberg, S., Ricard, M., & Singer, T. (2013b). Differential pattern of functional brain plasticity after compassion and empathy training. *Social Cognitive & Affective Neuroscience*, *9*(6), 873–879.

Koechlin, E. (2011). Frontal pole function: What is specifically human? *Trends in Cognitive Sciences*, *15*, 241.

Kornfield, J. (1979). Intensive insight meditation: A phenomenological study. *Journal of Transpersonal Psychology, 11*, 41–58.

Kozasa, E. H., Sato, J. R., Lacerda, S. S., Barreiros, M. A., Radvany, J., Russell, T. A., . . . Amaro, E. (2012). Meditation training increases brain efficiency in an attention task. *NeuroImage*, *59*, 745–749.

Kozhevnikov, M., Elliott, J., Shephard, J., & Gramann, K. (2013). Neurocognitive and somatic components of temperature increases during g-tummo meditation: Legend and reality. *PLoS One*, *8*, e58244.

Kramer, R. S., Weger, U. W., & Sharma, D. (2013). The effect of mindfulness meditation on time perception. *Consciousness and Cognition*, *22*, 846–852.

Krusche, A., Cyhlarova, E., & Williams, J. M. G. (2013). Mindfulness online: An evaluation of the feasibility of a web-based mindfulness course for stress, anxiety and depression. *British Medical Journal Open*, *3*.

Kuehner, C., & Weber, I. (1999). Responses to depression in unipolar depressed patients: An investigation of Nolen-Hoeksema's response styles theory. *Psychological Medicine*, *29*, 1323–1333.

Kuijpers, H. J., van der Heijden, F. M., Tuinier, S., & Verhoeven, W. M. (2007). Meditation-induced psychosis. *Psychopathology*, *40*, 461–464.

Kumar, S., Nagendra, H. R., Naveen, K. V., Manjunath, N. K., & Telles, S. (2010). Brainstem auditory-evoked potentials in two meditative mental states. *International Journal of Yoga*, *3*, 37–41.

Laird, A. R., Fox, P. M., Eickhoff, S. B., Turner, J. A., Ray, K. L., McKay, D. R., . . . Fox, P. T. (2011). Behavioral interpretations of intrinsic connectivity networks. *Journal of Cognitive Neuroscience*, *23*, 4022–4037.

Laird, A. R., McMillan, K. M., Lancaster, J. L., Kochunov, P., Turkeltaub, P. E., Pardo, J. V., & Fox, P. T. (2005). A comparison of label-based review and ALE meta-analysis in the Stroop task. *Human Brain Mapping*, *25*, 6–21.

Lazar, S. W., Kerr, C. E., Wasserman, R. H., Gray, J. R., Greve, D. N., Treadway, M. T., . . . Fischl, B. (2005). Meditation experience is associated with increased cortical thickness. *Neuroreport*, *16*, 1893–1897.

Ledesma, D., & Kumano, H. (2009). Mindfulness-based stress reduction and cancer: A meta-analysis. *Psycho-Oncology*, *18*, 571–579.

Lee, T., Leung, M. K., Hou, W. K., Tang, J. C., Yin, J., So, K. F., . . . Chan, C. C. (2012). Distinct neural activity associated with focused-attention meditation and loving-kindness meditation. *PLoS ONE*, *7*, e40045.

Lehrer, P., Sasaki, Y., & Saito, Y. (1999). Zazen and cardiac variability. *Psychosomatic Medicine*, *61*, 812–821.

Leiberg, S., Klimecki, O., & Singer, T. (2011). Short-term compassion training increases prosocial behavior in a newly developed prosocial game. *PloS One*, *6*, e17798.

Lesh, T. V. (1970). Zen meditation and the development of empathy in counselors. *Journal of Humanistic Psychology, 10*, 39–74.

Leung, M. K., Chan, C. C., Yin, J., Lee, C. F., So, K. F., & Lee, T. M. (2013). Increased gray matter volume in the right angular and posterior parahippocampal gyri in loving-kindness meditators. *Social Cognitive & Affective Neuroscience*, *8*, 34–39.

Levenson, R. W., Ekman, P., & Ricard, M. (2012). Meditation and the startle response: A case study. *Emotion*, *12*, 650–658.

Levinson, D. B., Stoll, E. L., Kindy, S. D., Merry, H. L., & Davidson, R. J. (2014). A mind you can count on: Validating breath counting as a behavioral measure of mindfulness. *Frontiers in Psychology*, *5*.

Liddell, B. J., Brown, K. J., Kemp, A. H., Barton, M. J., Das, P., Peduto, A., . . . Williams, L. M. (2005). A direct brainstem-amygdala-cortical "alarm" system for subliminal signals of fear. *NeuroImage, 24*, 235–243.

Lin, P., Chang, J., Zemon, V., & Midlarsky, E. (2008). Silent illumination: A study on Chan (Zen) meditation, anxiety, and musical performance quality. *Psychology of Music, 36*, 139–155.

Lindahl, J. R., Kaplan, C. T., Winget, E. M., & Britton, W. B. (2014). A phenomenology of meditation-induced light experiences: Traditional buddhist and neurobiological perspectives. *Frontiers in Psychology*, *4*.

Linehan, M. (1993). *Cognitive-behavioral treatment of borderline personality disorder*. New York: Guilford.

Lipsey, M. W., & Wilson, D. B. (1993). The efficacy of psychological, educational, and behavioral treatment. Confirmation from meta-analysis. *The American Psychologist*, *48*, 1181–1209.

Lloyd, D. M., Lewis, E., Payne, J., & Wilson, L. (2012). A qualitative analysis of sensory phenomena induced by perceptual deprivation. *Phenomenology and the Cognitive Sciences*, *11*, 95–112.

Lo, P. C., Huang, M. L., & Chang, K. M. (2003). EEG alpha blocking correlated with perception of inner light during Zen meditation. *The American Journal of Chinese Medicine*, *31*, 629–642.

Lou, H. C., Kjaer, T. W., Friberg, L., Wildschiodtz, G., Holm, S., & Nowak, M. (1999). A 15O-H2O PET study of meditation and the resting state of normal consciousness. *Human Brain Mapping*, *7*, 98–105.

Luders, E. (2014). Exploring age-related brain degeneration in meditation practitioners. *Annals of the New York Academy of Sciences*, *1307*, 82–88.

Luders, E., Clark, K., Narr, K. L., & Toga, A. W. (2011). Enhanced brain connectivity in long-term meditation practitioners. *NeuroImage*, *57*, 1308–1316.

Luders, E., Thompson, P. M., Kurth, F., Hong, J. Y., Phillips, O. R., Wang, Y., . . . Toga, A. W. (2013). Global and regional alterations of hippocampal anatomy in long-term meditation practitioners. *Human Brain Mapping*, *34*, 3369–3375.

Luders, E., Toga, A. W., Lepore, N., & Gaser, C. (2009). The underlying anatomical correlates of long-term meditation: Larger hippocampal and frontal volumes of gray matter. *NeuroImage*, *45*, 672–678.

Lutz, A., Dunne, J. D., & Davidson, R. J. (2007). Meditation and the neuroscience of consciousness: An introduction. In P. D. Zelazo, M. Moscovtich, & E. Thompson (Eds.), *The Cambridge handbook of consciousness* (pp. 499–551). New York: Cambridge University Press.

Lutz, A., Greischar, L. L., Perlman, D. M., & Davidson, R. J. (2009). BOLD signal in insula is differentially related to cardiac function during compassion meditation in experts vs. novices. *NeuroImage*, *47*, 1038–1046.

Lutz, A., McFarlin, D. R., Perlman, D. M., Salomons, T. V., & Davidson, R. J. (2013). Altered anterior insula activation during anticipation and experience of painful stimuli in expert meditators. *NeuroImage*, *64*, 538–546.

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences, 12*, 163–169.

Lykins, E. L. B., & Baer, R. A. (2009). Psychological functioning in a sample of long-term practitioners of mindfulness meditation. *Journal of Cognitive Psychotherapy, 23*, 226–241.

Lynch, S., Gander, M. L., Kohls, N., Kudielka, B., & Walach, H. (2011). Mindfulness-based coping with university life: A non-randomized wait-list-controlled pilot evaluation. *Stress and Health*, *27*, 365–375.

MacKenzie C. S., Poulin, P. A., & Seidman-Carlson, R. (2006). A brief mindfulness-based stress reduction intervention for nurses and nurse aides. *Applied Nursing Research, 19*, 105–109.

MacLean, K. A., Ferrer, E., Aichele, S. R., Bridwell, D. A., Zanesco, A. P., Jacobs, T. L., . . . Wallace, B. A. (2010). Intensive meditation training improves perceptual discrimination and sustained attention. *Psychological Science*, *21*, 829–839.

Maguire, E. A., Gadian, D. G., Johnsrude, I. S., Good, C. D., Ashburner, J., Frackowiak, R. S., & Frith, C. D. (2000). Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences*, *97*, 4398–4403.

Makris, N., Kennedy, D. N., McInerney, S., Sorensen, A. G., Wang, R., Caviness, V. S., & Pandya, D. N. (2005). Segmentation of subcomponents within the superior longitudinal fascicle in humans: A quantitative, in vivo, DT-MRI study. *Cerebral Cortex*, *15*, 854–869.

Malarkey, W. B., Jarjoura, D., & Klatt, M. (2013). Workplace based mindfulness practice and inflammation: A randomized trial. *Brain, Behavior, and Immunity*, *27*, 145–154.

Malinowski, P. (2013). Neural mechanisms of attentional control in mindfulness meditation. *Frontiers in Neuroscience*, *7*, 8.

Manna, A., Raffone, A., Perrucci, M. G., Nardo, D., Ferretti, A., Tartaro, A., . . . Romani, G. L. (2010). Neural correlates of focused attention and cognitive monitoring in meditation. *Brain Research Bulletin*, *82*, 46–56.

Manocha, R. (2000). Why meditation? *Australian Family Physician*, *29*, 1135–1138.

Mascaro, J. S., Rilling, J. K., Negi, L. T., & Raison, C. L. (2013a). Compassion meditation enhances empathic accuracy and related neural activity. *Social Cognitive & Affective Neuroscience*, *8*, 48–55.

Mascaro, J. S., Rilling, J. K., Negi, L. T., & Raison, C. L. (2013b). Pre-existing brain function predicts subsequent practice of mindfulness and compassion meditation. *NeuroImage*, *69*, 35–42.

Mason, O. J., & Brady, F. (2009). The psychotomimetic effects of short-term sensory deprivation. *The Journal of Nervous and Mental Disease*, *197*, 783–785.

McCall, C., Steinbeis, N., Ricard, M., & Singer, T. (2014). Compassion meditators show less anger, less punishment, and more compensation of victims in response to fairness violations. *Frontiers in Behavioral Neuroscience*, *8*.

McEvoy, T. M., Frumkin, L. R., & Harkins, S. W. (1980). Effects of meditation on brainstem auditory evoked potentials. *International Journal of Neuroscience, 10*, 165–170.

McNaughton, N. (2006). The role of the subiculum within the behavioural inhibition system. *Behavioural Brain Research, 174*, 232–250.

Melloni, M., Sedeño, L., Couto, B., Reynoso, M., Gelormini, C., Favaloro, R., . . . Ibanez, A. (2013). Preliminary evidence about the effects of meditation on interoceptive sensitivity and social cognition. *Behavioral and Brain Functions*, *9*.

Metzinger, T. (2004). *Being no one: The self-model theory of subjectivity*. Boston: MIT Press.

Mirams, L., Poliakoff, E., Brown, R. J., & Lloyd, D. M. (2013). Brief body-scan meditation practice improves somatosensory perceptual decision making. *Consciousness and Cognition*, *22*, 348–359.

Mitchell, J. T., McIntyre, E. M., English, J. S., Dennis, M. F., Beckham, J. C., & Kollins, S. H. (2013). A pilot trial of mindfulness meditation training for ADHD in adulthood: Impact on core symptoms, executive functioning, and emotion dysregulation. *Journal of Atention Disorders*. Online advance publication.

Mitchell, J. T., Nelson-Gray, R. O., & Anastopoulos, A. D. (2008). Adapting an emerging empirically supported cognitive-behavioral therapy for adults with ADHD and comorbid complications: An example of two case studies. *Clinical Case Studies*, *7*(5), 423–448.

Mitchell, J. T., Zylowska, L., & Kollins, S. H. (2015). Mindfulness meditation training for attention-deficit/hyperactivity disorder in adulthood: Current empirical support, treatment overview, and future directions. *Cognitive and Behavioral Practice*, *22*, 172–191.

Moore, A., Gruber, T., Derose, J., & Malinowski, P. (2012). Regular, brief mindfulness meditation practice improves electrophysiological markers of attentional control. *Frontiers in Human Neuroscience*, *6*.

Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness and Cognition*, *18*, 176–186.

Mor, N., and Winquist, J. (2002). Self-focused attention and negative affect: A meta-analysis. *Psychological Bulletin, 128*, 638–662.

Morone, N. E., Greco, C. M., & Weiner, D. K. (2008). Mindfulness meditation for the treatment of chronic low back pain in older adults: A randomized controlled pilot study. *PAIN*, *134*, 310–319.

Morrison, A. B., Goolsarran, M., Rogers, S. L., & Jha, A. P. (2013). Taming a wandering attention: Short-form mindfulness training in student cohorts. *Frontiers in Human Neuroscience*, *7*.

Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. *Psychological Science*, *24* 776–781.

Nakao, M., Yano, E., Nomura, S., & Kuboki, T. (2003). Blood pressure-lowering effects of biofeedback treatment in hypertension: A meta-analysis of randomized controlled trials. *Hypertension Research*, *26*, 37–46.

Namdak, L. T. (2006). *Bonpo dzogchen teachings.* Edited and translated by J. M. Reynolds. Kathmandu, Nepal: Vajra.

Naranjo, J. R., & Schmidt, S. (2012). Is it me or not me? Modulation of perceptual-motor awareness and visuomotor performance by mindfulness meditation. *BMC Neuroscience*, *13*.

Neff, K. D., & Germer, C. K. (2013). A pilot study and randomized controlled trial of the mindful self-compassion program. *Journal of Clinical Psychology*, *69*, 28–44.

Nestoriuc, Y., & Martin, A. (2007). Efficacy of biofeedback for migraine: A meta-analysis. *PAIN*, *128*, 111–127.

Nestoriuc, Y., Rief, W., & Martin, A. (2008). Meta-analysis of biofeedback for tension-type headache: Efficacy, specificity, and treatment moderators. *Journal of Consulting and Clinical Psychology*, *76*, 379–396.

Newberg, A. B. (2014). The neuroscientific study of spiritual practices. *Frontiers in Psychology*, *5*.

Nolen-Hoeksema, S. (2000). The role of rumination in depressive disorders and mixed anxiety/depressive symptoms. *Journal of Abnormal Psychology*, *109*, 504–511.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain—A meta-analysis of imaging studies on the self. *NeuroImage*, *31*, 440–457.

Nyklíček, I., & Kuipers, E. (2008). Effects of mindfulness-based stress reduction intervention on psychological well-being and quality of life: Is increased mindfulness indeed the mechanism? *Annals of Behavioral Medicine, 35*, 331–340

Nyklíček, I., Mommersteeg, P., Van Beugen, S., Ramakers, C., & Van Boxtel, G. J. (2013). Mindfulness-based stress reduction and physiological activity during acute stress: A randomized controlled trial. *Health Psychology*, *32*(10), 1110.

Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D., & Gross, J. J. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage*, *23*(2), 483–499.

Oken, B. S., Fonareva, I., Haas, M., Wahbeh, H., Lane, J. B., Zajdel, D., & Amen, A. (2010). Pilot controlled trial of mindfulness meditation and education for dementia caregivers. *The Journal of Alternative and Complementary Medicine*, *16*, 1031–1038.

O'Leary, K., & Dockray, S. (2015). The effects of two novel gratitude and mindfulness interventions on well-being. *The Journal of Alternative and Complementary Medicine*, *21*, 243–245.

Olesen, P. J., Nagy, Z., Westerberg, H., & Klingberg, T. (2003). Combined analysis of DTI and fMRI data reveals a joint maturation of white and grey matter in a fronto-parietal network. *Cognitive Brain Research*, *18*, 48–57.

Olivers, C. N., & Nieuwenhuis, S. (2005). The beneficial effect of concurrent task-irrelevant mental activity on temporal attention. *Psychological Science*, *16*, 265–269.

Olivers, C. N., & Nieuwenhuis, S. (2006). The beneficial effects of additional task load, positive affect, and instruction on the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance*, *32*, 364–379.

Oman, D., Shapiro, S. L., Thoresen, C. E., Flinders, T., Driskill, J. D., & Plante, T. G. (2007). Learning from spiritual models and meditation: A randomized evaluation of a college course. *Pastoral Psychology, 55*, 473–493.

O'Mara, S. (2005). The subiculum: What it does, what it might do, and what neuro-anatomy has yet to tell us. *Journal of Anatomy*, *207*, 271–282.

Omata, K., Hanakawa, T., Morimoto, M., & Honda, M. (2013). Spontaneous slow fluctuation of EEG alpha rhythm reflects activity in deep-brain structures: A simultaneous EEG-fMRI study. *PLoS ONE*, *8*, e66869.

Orme-Johnson, D. W. (1973). Autonomic stability and transcendental meditation. *Psychosomatic Medicine, 35*, 341–349.

Ortner, C. N. M., Kilner, S. J., & Zelazo, P. D. (2007). Mindfulness meditation and reduced emotional interference on a cognitive task. *Motivation and Emotion, 31*, 271–283.

Ott, U., Hölzel, B.K., & Vaitl, D. (2011). Brain structure and meditation. How spiritual practice shapes the brain. In H. Walach, S. Schmidt, & W. B.Jonas (Eds.), *Neuroscience, consciousness and spirituality. Proceedings of the expert meeting in Freiburg/Breisgau 2008.* Berlin: Springer.

Ozawa-de Silva, B., & Dodson-Lavelle, B. (2011). An education of heart and mind: Practical and theoretical issues in teaching cognitive-based compassion training to children. *Practical Matters*, *1*, 1–28.

Pace, T. W., Negi, L. T., Adame, D. D., Cole, S. P., Sivilli, T. I., Brown, T. D., . . . Raison, C. L. (2009). Effect of compassion meditation on neuroendocrine, innate immune and behavioral responses to psychosocial stress. *Psychoneuroendocrinology*, *34*, 87–98.

Pagano, R. R., Rose, R. M., Stivers, R. M., & Warrenburg, S. (1976). Sleep during Transcendental Meditation. *Science*, *191*, 308–310.

Pagnoni, G., & Cekic, M. (2007). Age effects on gray matter volume and attentional performance in Zen meditation. *Neurobiology of Aging*, *28*, 1623–1627.

Pagnoni, G., Cekic, M., & Guo, Y. (2008). "Thinking about not-thinking": Neural correlates of conceptual processing during Zen meditation. *PLoS One*, *3*, e3083.

Pattanashetty, R., Sathiamma, S., Talakkad, S., Nityananda, P., Trichur, R., & Kutty, B. M. (2010). Practitioners of vipassana meditation exhibit enhanced slow wave sleep and REM sleep states across different age groups. *Sleep and Biological Rhythms*, *8*, 34–41.

Penfield, W., & Erickson, T. C. (1941). *Epilepsy and cerebral localization: A study of the mechanism, treatment and prevention of epileptic seizures*. Springfield, IL: Thomas.

Perez-De-Albeniz, A., & Holmes, J. (2000). Meditation: Concepts, effects and uses in therapy. *International Journal of Psychotherapy*, *5*, 49–58.

Perlman, D. M., Salomons, T. V., Davidson, R. J., & Lutz, A. (2010). Differential effects on pain intensity and unpleasantness of two meditation practices. *Emotion*, *10*, 65–71.

Persinger, M. A. (1983). Religious and mystical experiences as artifacts of temporal lobe function: A general hypothesis. *Perceptual and Motor Skills*, *57*, 1255–1262.

Pettersson, R., Söderström, S., Edlund-Söderström, K., & Nilsson, K. W. (2014). Internet-based cognitive behavioral therapy for adults with ADHD in outpatient psychiatric care: A randomized trial. *Journal of Attention Disorders*. Online advance publication.

Phan, K. L., Taylor, S. F., Welsh, R. C., Decker, L. R., Noll, D. C., Nichols, T. E., . . . Liberzon, I. (2003). Activation of the medial prefrontal cortex and extended amygdala by individual ratings of emotional arousal: A fMRI study. *Biological Psychiatry*, *53*, 211–215.

Phang, C. K., Mukhtar, F., Ibrahim, N., Keng, S. L., & Mohd, S. S. (2015). Effects of a brief mindfulness-based intervention program for stress management among medical students: The Mindful-Gym randomized controlled study. *Advances in Health Sciences Education: Theory and Practice*, *20*, 1115–1134.

Philipsen, A., Richter, H., Peters, J., Alm, B., Sobanski, E., Colla, M., . . . van Elst, L. T. (2007). Structured group psychotherapy in adults with attention deficit hyperactivity disorder: Results of an open multicentre study. *The Journal of Nervous and Mental Disease*, *195*, 1013–1019.

Phongsuphap, S., Pongsupap, Y., Chandanamattha, P., & Lursinsap, C. (2008). Changes in heart rate variability during concentration meditation. *International Journal of Cardiology*, *130*, 481–484.

Pickert, K. (2014). The mindful revolution. *Time*, *23*, 40–49.

Piet, J., & Hougaard, E. (2011). The effect of mindfulness-based cognitive therapy for prevention of relapse in recurrent major depressive disorder: A systematic review and meta-analysis. *Clinical Psychology Review*, *31*, 1032–1040.

Prakash, R. S., Hussain, M. A., & Schirda, B. (2015). The role of emotion regulation and cognitive control in the association between mindfulness disposition and stress. *Psychology and Aging*, *30*, 160–171.

Purser, R. E. (2014). Clearing the muddled path of traditional and contemporary mindfulness: A response to Monteiro, Musten, and Compson. *Mindfulness*, *6*, 1–23.

Purser, R., & Loy, D. (2013). Beyond McMindfulness. *Huffington Post*. Retrieved from http://www.huffingtonpost.com/ron-purser/beyond-mcmindfulness_b_3519289.html.

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences*, *98*, 676–682.

Rief, W., Nestoriuc, Y., Weiss, S., Welzel, E., Barsky, A. J., & Hofmann, S. G. (2009). Meta-analysis of the placebo response in antidepressant trials. *Journal of Affective Disorders*, *118*, 1–8.

Robinson, F. P., Mathews, H. L., & Witek-Janusek, L. (2003). Psycho-endocrine-immune response to mindfulness-based stress reduction in individuals infected with the human immunodeficiency virus: A quasiexperimental study. *The Journal of Alternative & Complementary Medicine*, *9*, 683–694.

Ruocco, A. C., & Direkoglu, E. (2013). Delineating the contributions of sustained attention and working memory to individual differences in mindfulness. *Personality and Individual Differences*, *54*, 226–230.

Ryff, C. D. (1989). Happiness is everything, or is it? Explorations on the meaning of psychological well-being. *Journal of Personality and Social Psychology*, *57*, 1069–1081.

Sahdra, B. K., MacLean, K. A., Ferrer, E., Shaver, P. R., Rosenberg, E. L., Jacobs, T. L., . . . Mangun, G. R. (2011). Enhanced response inhibition during intensive meditation training predicts improvements in self-reported adaptive socioemotional functioning. *Emotion*, *11*, 299–312.

Salardini, A., Narayanan, N. S., Arora, J., Constable, T., & Jabbari, B. (2012). Ipsilateral synkinesia involves the supplementary motor area. *Neuroscience Letters, 523*, 135–138.

Salzberg, S. (2010). *Real happiness: The power of meditation: A 28-day program*. New York: Workman.

Sanmuganathan, P. S., Ghahramani, P., Jackson, P. R., Wallis, E. J., & Ramsay, L. E. (2001). Aspirin for primary prevention of coronary heart disease: Safety and absolute benefit related to coronary risk derived from meta-analysis of randomised trials. *Heart*, *85*, 265–271.

Santorelli, S. (2014). *Mindfulness-based stress reduction (MBSR): Standards of practice*. Amherst, MA: Center for Mindfulness in Medicine, Health Care & Society.

Sauer, S., Walach, H., & Kohls, N. (2011a). Gray's behavioural inhibition system as a mediator of mindfulness towards well-being. *Personality and Individual Differences, 50*, 506–511.

Sauer, S., Walach, H., Schmidt, S., Hinterberger, T., Horan, M., & Kohls, N. (2011b). Implicit and explicit emotional behavior and mindfulness. *Consciousness and Cognition*, *20*(4), 1558–1569.

Sayadaw, M. (1994). *The progress of insight: A treatise on Buddhist satipatthana meditation*. Edited and translated by N. Thera. Kandy, Sri Lanka: Buddhist Publication Society.

Schoenbaum, G., & Esber, G. R. (2010). How do you (estimate you will) like them apples? Integration as a defining trait of orbitofrontal function. *Current Opinion in Neurobiology*, *20*, 205–211.

Schoenberg, P. L., Hepark, S., Kan, C. C., Barendregt, H. P., Buitelaar, J. K., & Speckens, A. E. (2014). Effects of mindfulness-based cognitive therapy on neurophysiological correlates of performance monitoring in adult attention-deficit/hyperactivity disorder. *Clinical Neurophysiology*, *125*, 1407–1416.

Sears, S., & Kraus, S. (2009). I think therefore I om: Cognitive distortions and coping style as mediators for the effects of mindfulness meditation on anxiety, positive and negative affect, and hope. *Journal of Clinical Psychology, 65*, 561–573.

Sears, S. R., Kraus, S., Carlough, K., & Treat, E. (2011). Perceived benefits and doubts of participants in a weekly meditation study. *Mindfulness*, *2*, 167–174.

Sedlmeier, P., Eberth, J., Schwarz, M., Zimmermann, D., Haarig, F., Jaeger, S., & Kunze, S. (2012). The psychological effects of meditation: A meta-analysis. *Psychological Bulletin*, *138*, 1139–1171.

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., ... Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of Neuroscience*, *27*, 2349–2356.

Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2002). *Mindfulness-based cognitive therapy for depression: A new approach to relapse prevention*. New York: Guilford.

Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2013). *Mindfulness-based cognitive therapy for depression* (2nd ed.). New York: Guilford.

Sergent, J., Ohta, S., & MacDonald, B. (1992). Functional neuroanatomy of face and object processing. A positron emission tomography study. *Brain*, *115*, 15–36.

Shankman, R. (2008). *The experience of Samadhi: An in-depth exploration of Buddhist meditation*. Boston: Shambhala.

Shankman, R. (2015). *The art and skill of Buddhist meditation: Mindfulness, concentration, and insight*. Oakland, CA: New Harbinger.

Shapiro, D. H. Jr. (1992). Adverse effects of meditation: A preliminary investigation of long-term meditators. *International Journal of Psychosomatics, 39*, 62–67.

Shapiro, S. L., Brown, K. W., & Biegel, G. M. (2007). Teaching self-care to caregivers: Effects of mindfulness-based stress reduction on the mental health of therapists in training. *Training and Education in Professional Psychology, 1*, 105–111.

Shapiro, S. L., Brown, K. W., Thoresen, C., & Plante, T. G. (2011). The moderation of mindfulness-based stress reduction effects by trait mindfulness: Results from a randomized controlled trial. *Journal of Clinical Psychology*, *67*, 267–277.

Shapiro, S. L., Carlson, L. E., Astin, J. A., & Freedman, B. (2006). Mechanisms of mindfulness. *Journal of Clinical Psychology, 62*, 373–386.

Shapiro, S. L., Oman, D., Thoresen, C. E., Plante, T. G., & Flinders, T. (2008). Cultivating mindfulness: Effects on well-being. *Journal of Clinical Psychology, 64*, 840–862.

Shapiro, S. L., Schwartz, G. E., & Bonner, G. (1998). Effects of mindfulness-based stress reduction on medical and premedical students. *Journal of Behavioral Medicine, 21*, 581–599.

Sharma, M., & Rush, S. E. (2014). Mindfulness-based stress reduction as a stress management intervention for healthy individuals: A systematic review. *Journal of Evidence-Based Complementary & Alternative Medicine*, *19*, 271–286.

Shiba, K., Nishimoto, M., Sugimoto, M., & Ishikawa, Y. (2015). The association between meditation practice and job performance: A cross-sectional study. *PloS One*, *10*, e0128287.

Shonin, E., Van Gordon, W., Slade, K., & Griffiths, M. D. (2013). Mindfulness and other Buddhist-derived interventions in correctional settings: A systematic review. *Aggression and Violent Behavior*, *18*, 365–372.

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science*, *15*, 243–256.

Silverstein, R. G., Brown, A. C., Roth, H. D., & Britton, W. B. (2011). Effects of mindfulness training on body awareness to sexual stimuli: Implications for female sexual dysfunction. *Psychosomatic Medicine*, *73*, 817–825.

Singh, N. N., Singh, A. N., Lancioni, G. E., Singh, J., Winton, A. S., & Adkins, A. D. (2010). Mindfulness training for parents and their children with ADHD increases the children's compliance. *Journal of Child and Family Studies*, *19*, 157–166.

Singleton, O., Hölzel, B. K., Vangel, M., Brach, N., Carmody, J., & Lazar, S. W. (2014). Change in brainstem gray matter concentration following a mindfulness-based intervention is correlated with improvement in psychological well-being. *Frontiers in Human Neuroscience*, *8*.

Slagter, H. A., Lutz, A., Greischar, L. L., Francis, A. D., Nieuwenhuis, S., Davis, J. M., . . . Richard, J. (2007). Mental training affects distribution of limited brain resources. *PLoS Biology*, *5*, e138.

Smith, S. M., Fox, P. T., Miller, K. L., Glahn, D. C., Fox, P. M., Mackay, C. E., . . . Beckmann, C. F. (2009). Correspondence of the brain's functional architecture during activation and rest. *Proceedings of the National Academy of Sciences*, *106*, 13040–13045.

Snippe, E., Nyklíček, I., Schroevers, M. J., & Bos, E. H. (2015). The temporal order of change in daily mindfulness and affect during mindfulness-based stress reduction. *Journal of Counseling Psychology*, *62*, 106–114.

Song, Y., & Lindquist, R. (2015). Effects of mindfulness-based stress reduction on depression, anxiety, stress and mindfulness in Korean nursing students. *Nurse Education Today*, *35*, 86–90.

Sood, A., Sharma, V., Schroeder, D. R., & Gorman, B. (2014). Stress management and resiliency training (SMART) program among department of radiology faculty: A pilot randomized clinical trial. *Explore: The Journal of Science and Healing*, *10*, 358–363.

Spasojeviç, J., & Alloy, L. B. (2001). Rumination as a common mechanism relating depressive risk factors to depression. *Emotion*, *1*, 25–37.

Sperduti, M., Martinelli, P., & Piolino, P. (2012). A neurocognitive model of meditation based on activation likelihood estimation (ALE) meta-analysis. *Consciousness and Cognition*, *21*, 269–276.

Spreng, R. N., Sepulcre, J., Turner, G. R., Stevens, W. D., & Schacter, D. L. (2013). Intrinsic architecture underlying the relations among the default, dorsal attention, and frontoparietal control networks of the human brain. *Journal of Cognitive Neuroscience*, *25*, 74–86.

Sucala, M., & David, D. (2013). Mindful about time in a fast forward world. The effects of mindfulness exercise on time perception. *Transylvanian Journal of Psychology*, *14*, 243–253.

Sze, J. A., Gyurak, A., Yuan, J. W., & Levenson, R. W. (2010). Coherence between emotional experience and physiology: Does body awareness training have an impact? *Emotion*, *10*, 803–814.

Tacon, A. M., McComb, J., Caldera, Y., & Randolph, P. (2003). Mindfulness meditation, anxiety reduction, and heart disease: A pilot study. *Family & Community Health: Journal of Health Promotion & Maintenance, 26*, 25–33.

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience*, *16*, 213–225.

Tang, Y. Y., Lu, Q., Geng, X., Stein, E. A., Yang, Y., & Posner, M. I. (2010). Short-term meditation induces white matter changes in the anterior cingulate. *Proceedings of the National Academy of Sciences*, *107*, 15649–15652.

Tang, Y. Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., . . . Fan, M. (2009). Central and autonomic nervous system interaction is altered by short-term meditation. *Proceedings of the National Academy of Sciences*, *106*, 8865–8870.

Tang, Y. Y., Rothbart, M. K., & Posner, M. I. (2012). Neural correlates of establishing, maintaining, and switching brain states. *Trends in Cognitive Sciences*, *16*, 330–337.

Taylor, B. L., Strauss, C., Cavanagh, K., & Jones, F. (2014). The effectiveness of self-help mindfulness-based cognitive therapy in a student sample: A randomised controlled trial. *Behaviour Research and Therapy*, *63*, 63–69.

Telles, S., & Naveen, K. V. (2004). Changes in middle latency auditory evoked potentials during meditation. *Psychological Reports, 94*, 398–400.

Teper, R., & Inzlicht, M. (2013). Meditation, mindfulness and executive control: The importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive & Affective Neuroscience*, *8*, 85–92.

Testa, C., Laakso, M.P., Sabattoli, F., Rossi, R., Beltramello, A., Soininen, H., Frisoni, G.B., 2004. A comparison between the accuracy of voxel-based morphometry and hippocampal volumetry in Alzheimer's disease. *Journal of Magnetic Resonance Imaging 19*, 274–282.

Tipsord, J. M. (2009). *The effects of mindfulness training and individual differences in mindfulness on social perception and empathy* (Doctoral dissertation). University of Oregon.

Tomasino, B., Fregona, S., Skrap, M., & Fabbro, F. (2012). Meditation-related activations are modulated by the practices needed to obtain it and by the expertise: An ALE meta-analysis study. *Frontiers in Human Neuroscience*, *6*.

Travis, F., & Wallace, R. K. (1997). Autonomic patterns during respiratory suspensions: Possible markers of transcendental consciousness. *Psychophysiology*, *34*, 39–46.

Trungpa, C. (2010). *Meditation in action*. Boston: Shambhala.

Uttal, W. R. (2001). *The new phrenology: The limits of localizing cognitive processes in the brain*. Cambridge, MA: MIT Press.

Vago, D. R., & Silbersweig, D. A. (2012). Self-awareness, self-regulation, and self-transcendence (S-ART): A framework for understanding the neurobiological mechanisms of mindfulness. *Frontiers in Human Neuroscience*, *6*.

Valentine, E. R., & Sweet, P. L. (1999). Meditation and attention: A comparison of the effects of concentrative and mindfulness meditation on sustained attention. *Mental Health, Religion & Culture*, *2*(1), 59–70.

Van den Hurk, P. A. M., Giommi, F., Gielen, S. C., Speckens, A. E. M., & Barendregt, H. P. (2010). Greater efficiency in attentional processing related to mindfulness meditation. *The Quarterly Journal of Experimental Psychology, 63*, 1168–1180.

Van den Hurk, P. A., Wingens, T., Giommi, F., Barendregt, H. P., Speckens, A. E., & van Schie, H. T. (2011). On the relationship between the practice of mindfulness meditation and personality—An exploratory analysis of the mediating role of mindfulness skills. *Mindfulness*, *2*, 194–200.

van der Meer, L., Costafreda, S., Aleman, A., & David, A. S. (2010). Self-reflection and the brain: A theoretical review and meta-analysis of neuroimaging studies with implications for schizophrenia. *Neuroscience & Biobehavioral Reviews*, *34*, 935–946.

Van der Oord, S., Bögels, S. M., & Peijnenburg, D. (2012). The effectiveness of mindfulness training for children with ADHD and mindful parenting for their parents. *Journal of Child and Family Studies*, *21*, 139–147.

Van der Velden, A. M., Kuyken, W., Wattar, U., Crane, C., Pallesen, K. J., Dahlgaard, J., . . . Piet, J. (2015). A systematic review of mechanisms of change in mindfulness-based cognitive therapy in the treatment of recurrent major depressive disorder. *Clinical Psychology Review*, *37*, 26–39.

Van de Weijer-Bergsma, E., Formsma, A. R., de Bruin, E. I., & Bögels, S. M. (2012). The effectiveness of mindfulness training on behavioral problems and attentional functioning in adolescents with ADHD. *Journal of Child and Family Studies*, *21*, 775–787.

Van Gordon, W., Shonin, E., Sumich, A., Sundin, E. C., & Griffiths, M. D. (2014). Meditation awareness training (MAT) for psychological well-being in a sub-clinical sample of university students: A controlled pilot study. *Mindfulness*, *5*, 381–391.

van Leeuwen, S., Muller, N. G., & Melloni, L. (2009). Age effects on attentional blink performance in meditation. *Consciousness and Cognition, 18*, 593–599.

van Leeuwen, S., Singer, W., & Melloni, L. (2012). Meditation increases the depth of information processing and improves the allocation of attention in space. *Frontiers in Human Neuroscience*, *6*.

Van Vugt, M. K., & Slagter, H. A. (2014). Control over experience? Magnitude of the attentional blink depends on meditative state. *Consciousness and Cognition*, *23*, 32–39.

Varela, F. J. (1996). Neurophenomenology: A methodological remedy for the hard problem. *Journal of Consciousness Studies*, *3*, 330–349.

Veehof, M. M., Oskam, M. J., Schreurs, K. M., & Bohlmeijer, E. T. (2011). Acceptance-based interventions for the treatment of chronic pain: A systematic review and meta-analysis. *PAIN, 152*, 533–542.

Vestergaard-Poulsen, P., van Beek, M., Skewes, J., Bjarkam, C. R., Stubberup, M., Bertelsen, J., & Roepstorff, A. (2009). Long-term meditation is associated with increased gray matter density in the brain stem. *Neuroreport*, *20*, 170–174.

Vettese, L. C., Toneatto, T., Stea, J. N., Nguyen, L., & Wang, J. J. (2009). Do mindfulness meditation participants do their homework? And does it make a difference? A review of the empirical evidence. *Journal of Cognitive Psychotherapy*, *23*, 198–225.

Vieten, C., & Astin, J. (2008). Effects of a mindfulness-based intervention during pregnancy on prenatal stress and mood: Results of a pilot study. *Archives of Women's Mental Health*, *11*, 67–74.

Visted, E., Vøllestad, J., Nielsen, M. B., & Nielsen, G. H. (2014). The impact of group-based mindfulness training on self-reported mindfulness: A systematic review and meta-analysis. *Mindfulness*, *6*, 501–522.

Vøllestad, J., Nielsen, M. B., & Nielsen, G. H. (2012). Mindfulness-and acceptance-based interventions for anxiety disorders: A systematic review and meta-analysis. *British Journal of Clinical Psychology*, *51*, 239–260.

Vøllestad, J., Sivertsen, B., & Nielsen, G. H. (2011). Mindfulness-based stress reduction for patients with anxiety disorders: Evaluation in a randomized controlled trial. *Behaviour Research and Therapy*, *49*, 281–288.

Walach, H., Buchheld, N., Buttenmüller, V., Kleinknecht, N., & Schmidt, S. (2006). Measuring mindfulness—The Freiburg Mindfulness Inventory (FMI). *Personality and Individual Differences*, *40*, 1543–1555.

Walach, H., Nord, E., Zier, C., Dietz-Waschkowski, B., Kersig, S., & Schüpbach, H. (2007). Mindfulness-based stress reduction as a method for personnel development: A pilot evaluation. *International Journal of Stress Management, 14*, 188–198

Wallmark, E., Safarzadeh, K., Daukantaitė, D., & Maddux, R. E. (2013). Promoting altruism through meditation: An 8-week randomized controlled pilot study. *Mindfulness*, *4*, 223–234.

Wang, D. J., Rao, H., Korczykowski, M., Wintering, N., Pluta, J., Khalsa, D. S., & Newberg, A. B. (2011). Cerebral blood flow changes associated with different meditation practices and perceived depth of meditation. *Psychiatry Research: Neuroimaging*, *191*, 60–67.

Wenk-Sormaz, H. (2005). Meditation can reduce habitual responding. *Alternative Therapies in Health and Medicine*, *11*, 42–58.

Weng, H. Y., Fox, A. S., Shackman, A. J., Stodola, D. E., Caldwell, J. Z., Olson, M. C., . . . Davidson, R. J. (2013). Compassion training alters altruism and neural responses to suffering. *Psychological Science*, *24*(7), 1171–1180.

Wiebking, C., de Greck, M., Duncan, N. W., Heinzel, A., Tempelmann, C., & Northoff, G. (2011). Are emotions associated with activity during rest or interoception? An exploratory fMRI study in healthy subjects. *Neuroscience Letters*, *491*, 87–92.

Williams, M., & Penman, D. (2011). *Mindfulness: An eight-week plan for finding peace in a frantic world*. New York: Rodale.

Wilson, J. (2014). *Mindful America: Meditation and the mutual transformation of Buddhism and American culture*. New York: Oxford University Press.

Wilson, T. D., Reinhard, D. A., Westgate, E. C., Gilbert, D. T., Ellerbeck, N., Hahn, C., . . . Shaked, A. (2014). Just think: The challenges of the disengaged mind. *Science*, *345*, 75–77.

Winbush, N. Y., Gross, C. R., & Kreitzer, M. J. (2007). The effects of mindfulness-based stress reduction on sleep disturbance: A systematic review. *Explore: The Journal of Science and Healing*, *3*, 585–591.

Witek-Janusek, L., Albuquerque, K., Chroniak, K. R., Chroniak, C., Durazo-Arvizu, R., & Mathews, H. L. (2008). Effect of mindfulness based stress reduction on immune function, quality of life and coping in women newly diagnosed with early stage breast cancer. *Brain, Behavior, and Immunity*, *22*, 969–981.

Wittmann, M., Otten, S., Schötz, E., Sarikaya, A., Lehnen, H., Jo, H. G., . . . Meissner, K. (2015). Subjective expansion of extended time-spans in experienced meditators. *Frontiers in Psychology*, *5*.

Wolkove, N., Kreisman, H., Darragh, D., Cohen, C., & Frank, H. (1984). Effect of Transcendental Meditation on breathing and respiratory control. *Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology*, *56*, 607–612.

Woodrow, H. (1951). Time perception. In S. S. Stevens (Ed.), *Handbook of experimental psychology* (pp. 1224–1236). New York: Wiley.

Wu, S. D., & Lo, P. C. (2008). Inward-attention meditation increases parasympathetic activity: A study based on heart rate variability. *Biomedical Research*, *29*, 245–250.

Yorston, G. A. (2001). Mania precipitated by meditation: A case report and literature review. *Mental Health, Religion and Culture*, *4*, 209–213.

Younger, J., Adriance, W., & Berger, R. J. (1975). Sleep during transcendental meditation. *Perceptual and Motor Skills, 40*, 953–954.

Zautra, A. J., Fasman, R., Davis, M. C., & Arthur, D. (2010). The effects of slow breathing on affective responses to pain stimuli: An experimental study. *PAIN*, *149*, 12–18.

Zeidan, F., Gordon, N. S., Merchant, J., & Goolkasian, P. (2010). The effects of brief mindfulness meditation training on experimentally induced pain. *The Journal of Pain*, *11*, 199–209.

Zeidan, F., Martucci, K. T., Kraft, R. A., Gordon, N. S., McHaffie, J. G., & Coghill, R. C. (2011). Brain mechanisms supporting the modulation of pain by mindfulness meditation. *The Journal of Neuroscience*, *31*, 5540–5548.

Zenner, C., Herrnleben-Kurz, S., & Walach, H. (2014). Mindfulness-based interventions in schools: A systematic review and meta-analysis. *Frontiers in Psychology*, *5*.

Zylowska, L., Ackerman, D. L., Yang, M. H., Futrell, J. L., Horton, N. L., Hale, T. S., . . . Smalley, S. L. (2008). Mindfulness meditation training in adults and adolescents with ADHD: A feasibility study. *Journal of Attention Disorders*, *11*, 737–746.

{ INDEX }

Note: Italicized page numbers indicate a figure on the designated page. Page numbers followed by "n" and another number indicate a numbered endnote on the designated page.