Bachelor Degree Project

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NEURAL EFFECTS OF MINDFULNESS MEDITATION ON EMOTION REGULATION:

Differences Between Adolescents and Adults

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Abstract

The time of adolescence is marked by enhanced emotional experiences and difficulties with regulating one's emotions. One way to improve the adolescent's ability to regulate their emotions is to let them practice mindfulness meditation. The motivational drive behind this thesis is the question of what forms of mindfulness meditation are needed to give the highest increase in their emotion regulation-abilities. One problem is that while there exist neural studies on mindfulness meditation for adults, the research field of adolescent meditation lacks them. Because neural studies are needed to adequately answer this question, and the lack of brain imaging tools for this thesis, the focus here was to conduct some groundwork for this discussion. The first aim was to investigate the neural effects of mindfulness meditation on emotion regulation in adults and the second aim was to investigate to what extent we can generalize these neural effects to adolescents. To be able to theoretical discuss the second aim, neural and psychological studies on mindfulness meditation and emotion regulation were used as a base. The studies were grouped into five sub-categories based on age group and research field and then discussed with the help of developmental studies. Adult meditators had stronger functionality in regulatory brain regions than non-meditators during meditation and during the perception of negative stimuli. The discussion about the generalization of the adult neural patterns to adolescents showed that the findings were too diverse to come to any useful conclusions. Empirical and conceptual improvements, along with neural meditation studies on adolescents, are needed to improve the research field in both age groups.

Keywords: mindfulness meditation, emotion regulation, developmental differences

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1. Introduction

Emotions and adolescents are not always best friends. The combination of pubertal hormones and a not yet fully developed prefrontal cortex (PFC) makes adolescents emotional experiences more intense than other age groups (e.g., Silk, Steinberg, & Morris, 2003). What makes the not developed PFC relevant in this context is its responsibility for among others self-regulation of emotions and behavior (Gross, 1998). What can we do to help these adolescents to increase their well-being? One method that has grown in interest the latest decades is mindfulness meditation (MM) that comes in both traditional and secular forms. The most basic explanation of MM is to have a non-judgmental approach to the current experience (Hölzel, Ott, Hempel, et al., 2007) and one of the most common effects is increased well-being (Hölzel et al., 2011). The problem is that the concept of well-being is too wide for researchers to use as a measurable variable. Another common and more specific variable that improves is emotion regulation (ER) (e.g., (Hölzel, Ott, Hempel, et al., 2007), which is exactly what adolescents find themselves having difficulties with.

There are limitations in the research fields of both adults and adolescents. The latter field has fewer studies than adults and lacks studies on the neural responses of MM. Waters, Barsky, Ridd, and Allen (2015) reacted to this by saying that the ”traditional remit of schools was to develop the brainpower of students” (p. 128). Therefore they wondered why neural studies on adolescents have not been conducted. One reason to look at neural studies is mentioned in a discussion had by Kanske, Heissler, Schönfelder, and Wessa (2012). They found that emotion-state scores from participants with depression did not correlate to the changes in amygdala activity during ER (Kanske et al., 2012). If this is a general problem, it could result in misleading implications if we only look at psychological studies on MM and adolescents. To include neural studies should give a more truthful picture. Further, Waters et al. (2015) added that there is a need for more randomized controlled trials (RCT) to decide what forms of MM best fit different ages and types of schools. To argue for their conclusion, they among other things cited a study involving pre- and early adolescents (Schonert-Reichl & Lawlor, 2010) where the effects of a Mindfulness Education (ME) program were measured. One of the measured variables was their general self-concept. The results showed that the program had no effect of this variable in pre-adolescents, while there was a positive effect among early adolescents. One explanation of this difference is changes in development (Schonert-

Reichl & Lawlor, 2010). These results suggest that pre-adolescents is in need of another form of MM to change their view. As there is a need to differentiate between those two age groups, there is also a need to differentiate between adolescents and adults. This applies to all measured variables, including ER.

1.1 Aim and Structure

First of all, I chose to look at the variable of ER because I believe it is the most important variable to increase if one wants a better emotional life. Without the ability to handle our emotions, how can we ever feel well? Secondly, to be able to adequately investigate what forms of MM give the largest effects on adolescent's ability to regulate their emotions, we need to look at both psychological and neural studies. Because I do not have access to brain imaging tools, I cannot do this. The reason I still include the discussion and information about different forms of MM is that it is the motivational drive behind my thesis. Instead of trying to explicit investigate what forms of MM suit best for adolescents and their ER ability, I will conduct some theoretical groundwork for this discussion. This groundwork is based on the lack of neural MM-studies for adolescents. My first aim is to investigate the neural effects of MM on ER in adults. The underlying question to this first aim is what differences there are in neural effects regarding different forms of MM. My second aim is to investigate to what extent we can generalize the found neural effects in adults to adolescents.

Before I investigate my research questions, I start with a background of the concepts of MM, ER, and how they are related to each other. In addition, I look at the research field of MM and how the adult forms of MM have been adapted to fit the needs of adolescents. The gaps and limitations in the field are also included. To explain in more detail about how I conducted the systematic review, and about the inclusion and exclusion criteria for the chosen articles, I include a method-section. For the result-section, I look at five subcategories of studies. The main subcategory for investigating my first aim is indirect neural and psychological studies on the effect of MM on ER (MM/ER studies) in adults. The second subcategory is indirect psychological studies of the effect of MM on ER for adolescents. Because the latter studies lack the neural component I cannot investigate my second aim. I still include these studies because they are compared to the results of the psychological measurements in MM/ER adult studies. To be able to investigate my second aim I instead look at adult neural studies on MM and ER, separately. I compare the latter studies with indirect neural studies of ER on adolescents to find age differences. The neural studies of MM on adults is used to speculate about the expected differences in neural effects of MM by taking developmental differences into account. In addition, the inclusion of adult MM- and ER-studies make the relationship between MM and ER clearer. This in turn facilitates the understanding of the included adult MM/ER-studies. Due to the large number of reported brain regions in the result-tables, I choose focused regions of interest (ROIs) relevant to my thesis which I summarize in text. When discussing my two aims, I analyze the single findings on their own, how they overlap with findings from the other subcategories, and highlight results that on the superficial level look contradicting. After the discussion, I go through the limitations of the included studies and my thesis, suggest future directions and reach my conclusions.

2. Background

2.1 Mindfulness Meditation

The effects of practicing MM include improvements in cognitive functions, and in emotional, behavioral and physical responses (Hölzel et al., 2011), It lowers blood pressure, the levels of cortisol, and helps patients with among others eating disorders, anxiety, and chronic pain. MM originates from Buddhism and one of the traditional forms of MM is Vipassanā (insight) meditation where one explores one owns body and mind (Hart, 2011). Another traditional form is Zen, a form of Buddhism influenced by Chinese philosophy (Suzuki, 2019). Further, there are many secular adaptions of MM and maybe the most popular is mindfulness-based stress reduction (MBSR). It was developed by Jon Kabat-Zinn in 1979 to treat stress and pain in medical patients (Kabat-Zinn, 2003). The length of a course in MBSR is eight to 10 weeks, with one meeting every week. One of the meetings is a full day retreat (Bishop, 2002). There are several forms of mindfulness meditation involved in MBSR, all of them aiming at making the participants changing their automatic responses to a stressful situation to conscious responses. The base of MBSR is sitting meditation, where the participants sit up straight on a chair or on the floor with their legs crossed. They are told to focus on their breathing and to return the focus to their breathing when they realize that they are occupied by their thought and feelings. This shift back to breathing is taking place by accepting that their mind has wandered. Other practices during MBSR are body scan, yoga, and lectures about how stress and emotions express itself both mentally and physically. For homework, the participants meditate while listening to instructions played on audio cassettes. Other secular methods are mindfulness-based cognitive therapy (MBCT) (Chiesa, Serretti, & Jakobsen, 2013), integrative body-mind training (IBMT) (Tang et al., 2009), and FEEL (mindful self-awareness) (Lutz, Brühl, Scheerer, Jäncke, & Herwig, 2016).

One common distinction of MM is focused attention and open monitoring meditation (Lutz, Slagter, Dunne, & Davidson, 2008). One example of FA meditation is the seated meditation described before. After much practice of focused attention, one's ability to focus becomes a trait, and one's threshold for reacting to emotional stimuli seem to be lower. During open monitoring, one monitors the current experience with its flow of thought, emotions and sensory stimuli without having any explicit focus on any of it. The skill level of the latter is dependent on the skill level of the former. This is because one needs to be calm and focused to achieve this goal (Lutz et al., 2008).

The research field of MM. Participants span from first-time meditators to long-term meditators (Davidson & Kaszniak, 2015), and the experiments are conducted either during a meditative or non-meditative state. The latter paradigm is used to study the long-term effects of meditation on traits. There are several ways to measure the effects of MM, such as using psychological scales and looking at the neural activity (Hölzel et al., 2011). The standard procedure is to combine these two measurements in the same study and observe the relationship between them. This is related to the term *neural correlates* that is defined as “brain activity that corresponds with and is necessary to produce a particular experience” (”Neural correlate”, n.d.). The most common instruments to measure neural activity are electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). EEG measures the electric activity of the brain with the help of electrodes placed on the scalp, and an fMRI-machine measures the blood oxygen level dependent (BOLD) effect (Gazzaniga, Ivry, & Mangun, 2014). With other words, fMRI measures the changes in oxygen levels in the blood flow by looking at its magnetic properties. A common method when looking at neural connectivity is diffusion tensor imaging (DTI) where two related variables are fractional anisotropy (FA) and axial diffusivity (AD). FA is the measurement of water diffusion along white matter tracts (Kochunov et al., 2012). The larger the value of FA, the more restricted the diffusion of water is by the direction of fibers. Changes in AD are associated with changes in among others the caliber and density of axons (Tang, Lu, Fan, Yang, & Posner, 2012).

One example of using psychological scales is the Five Facet Mindfulness Questionnaire developed by Baer, Smith, Hopkins, Krietemeyer, and Toney (2006). The questionnaire was the result of an analysis of several other questionnaires, which showed that the concept of mindfulness could be divided into five factors. The participants score their self-perceived levels of describing, observing, reacting to and judging the current experience, and the levels of acting with awareness (Baer et al., 2006); ("Five Facet Mindfulness Questionnaire", n.d.).

Limitations in the research field of MM. One of the most fundamental problems is to define the concept of mindfulness. According to Chiesa et al. (2013), the debate includes questions such as if the older and newer definition of mindfulness can be considered equal. There also seem to exist parallel meanings of the term "mindfulness". Is it a trait, state, or is it the practice of meditation? (Chiesa et al., 2013). Davidson and Kaszniak (2015) discussed several problems concerning the validity of experimental studies. First, there is no research on the individual traits that make someone become a long-term meditator. This makes the current selection methods of meditators biased. Second, it is impossible to use double-blind placebo-controlled designs, which is usually used in research on medical interventions. Third, there is a lack of longitudinal studies, and fourth, when it comes to individual reports from meditation beginners, the attention to one's inner world can temporarily increase the experience of negative emotions. Others have reported additional consequences of MM, such as panic attacks and psychical pain (e.g., Cebolla, Demarzo, Martins, Soler, & Garcia-Campayo, 2017).

In addition to these problems, Davidson and Kaszniak (2015) referred to the term *reverse inference*, which is a problem in all research fields that uses neuroimaging. The process of reverse inference was described in Poldrack (2006):

> (1) In the present study, when task comparison A was presented, brain area Z was active.
> (2) In other studies, when cognitive process X was putatively engaged, then brain area Z was active.
> (3) Thus, the activity of area Z in the present study demonstrates engagement of cognitive process X by task comparison A. (p. 59)

Davidson and Kaszniak (2015) thought reasoning like this is problematic and asked which patterns and parameters should be accountable for a certain mental state. What makes this extra problematic in research on mindfulness is the already mentioned lack of a clear definition of what mindfulness is.

Hölzel et al. (2011) gave several suggestions on how to strengthen the research field of MM. Their first suggestion highlighted the importance of looking at the concept of MM through nuanced glasses, which will lead to more specific research questions. Their second suggestion was to applicate the carefully distinguished aspects of MM during considerations of the right treatment for different clinical disorders. This process will also help develop the research field of positive psychology by investigating how the minds of healthy individuals functions and flower (Hölzel et al., 2011).

2.2 Emotion Regulation

Thompson (1994) defined ER as “extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals” (p. 27-28). According to Gross (1998), the research field of ER goes back to Sigmund Freud’s psychodynamic view of regulation of anxiety. Freud's view later influenced the research field of stress and coping. The difference between the two fields is that Freud looked at only person variables, while the other also looks at variables bound in situations. They also differ in that the former includes regulation of positive emotions, while the latter does not. ER and coping are two of five subgroups of a wider concept called affect regulation (Gross, 1998). The third and fourth subgroups are mood regulation and mood repair that both have more focus on the actual experience than changes in behavioral responses, which ER have. Last, there are defenses, which mostly are not experienced consciously and where the negative experience is in focus (Gross, 1998).

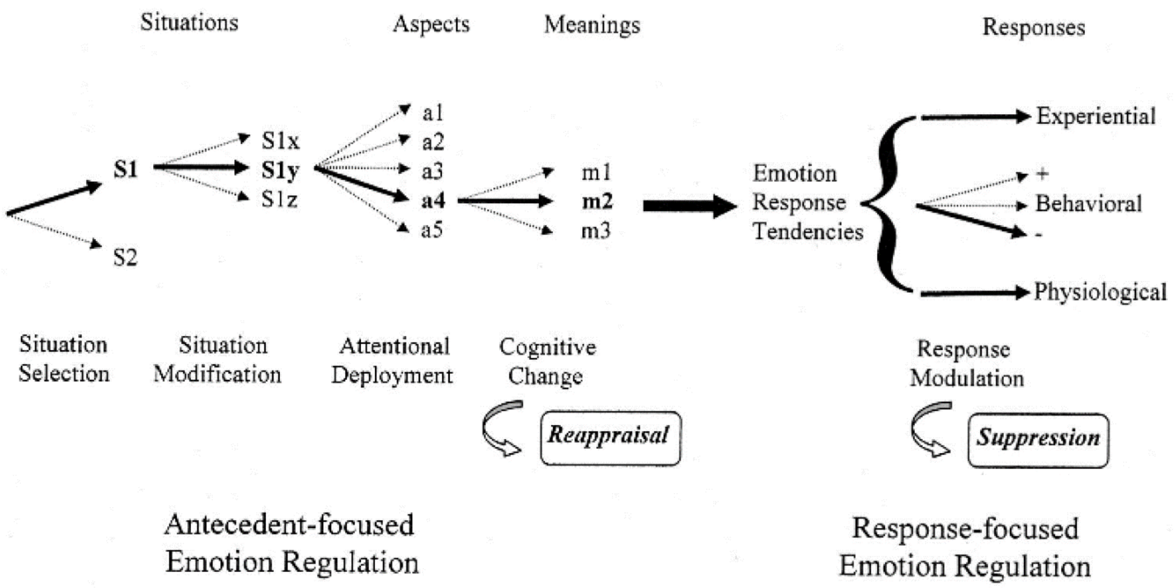

Figure 1. The process model of emotion regulation developed by James Gross. Reprinted from “Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being” by J. J. Gross and O. P. John, 2003, *Journal of Personality and Social Psychology, 85*(2), p. 349. Copyright 2003 by the American Psychological Association, Inc. Reprinted with permission.

In his *process model of emotion regulation* (Figure 1), Gross (1998) distinguished between two types of emotional strategies. The model can be described through a linear progress. Antecedent-focused strategies take place early in the progress, while response-focused strategies take place late in the progress. The progress line starts with situation selection. When one has selected what situation to be included in, the next step is to modify the situation. The third and fourth steps are attentional deployment, where one chose what to focus on in the situation, and cognitive change. The latter step is also called cognitive reappraisal (Gross, 2002). This is when one choose what meaning to attach to a current situation. The chosen meaning elicits ”emotional response tendencies, including behavioral, experiential, and physiological tendencies” (Gross, 1998, 282). The final step is to regulate these tendencies. One way to do this is by expressive-suppression (Gross, 2002), where one tries to inhibit ones behavioral responses related to the experienced emotion.

Another model is the dual-process framework that aims to shift the methods in literature search in the field of ER from exhaustive to strategic (Gyurak, Gross, & Etkin, 2011). The framework is a distinction between explicit and implicit ER but later developed into a four-dimensional model (Braunstein, Gross, & Ochsner (2017).

The two added factors in the latter study are controlled and automatic strategies. Reappraisal, selective attention, and distraction belong under explicit-controlled strategies, while implicit-automatic strategies involve experience-dependent affective learning. The two other dimensions are implicit-controlled and explicit-automatic strategies. An example of the former is when emotion regulation is a by-product of controlling other cognitive functions, while for the latter ER can be the result of for example the placebo effect.

The research field of ER. When it comes to the neural correlates of ER, earlier research has found no clear answers of which specific regions are responsible for which dimension. Braunstein et al. (2017) concluded that more neuroimaging studies are necessary to answer this question. It is easier to measure the psychological aspect of ER. One of the most common tools to do this is the 36 Item Cognitive Emotion Regulation Questionnaire (Garnefski, Kraaij, & Spinhoven, 2001), developed by extracting and reforming coping strategies from existing ER questionnaires. It consists of nine subcategories, e.g. acceptance, positive reappraisal, and catastrophizing.

2.3 Mindfulness Meditation and Emotion Regulation

One debate in the combined research fields of MM and ER is how large the overlap is between the two concepts and their involved brain regions. Even if overlaps have been observed, there have on the surface been contradicting results. Hölzel et al. (2011) observed that some studies showed that MM is related to non-appraisal strategies, while other studies showed that it is related to appraisal strategies. They asked if MM should be seen as controlling or accepting one’s emotions. Their suggested explanation of the different results was that there could be a difference between beginners and expert meditators. The former would require more cognitive control to be able to accept the current experience than the latter. Chiesa et al. (2013) made the same difference, using the terms *top-down*-and *bottom-up* ER strategies, and aimed to answer the question asked above by reviewing neuroimaging studies. On the basis of their findings, they suggested that top-down ER is shown in short-term meditators, while bottom-up ER is shown in long-term meditators. It could also be that the degree of alterations between the two strategies could be affected by the form of MM and what kind of instructors there is (Chiesa et al., 2013).

2.4 The Research Field of MM and Adolescents

Adapted methods for adolescents. There exist many mindfulness programs for adolescents in both schools, home, and clinical environments. For example, Broderick and Metz (2009) developed the Learning to BREATHE program by taking standards of school health and school counselors into account. In addition, they looked at several aspects of the development of adolescents. Some of these aspects were the need for adolescents to find their identity and their sometimes confusing reactions to their own emotions (Broderick & Blewitt, 2003). The aim of the program is to improve the ability to regulate one's emotions, made possible by among other things understanding one’s thoughts and feelings and being aware of one’s body (Broderick & Metz, 2009). The participants further practice meditation at home with the aid from workbooks and CDs. Another example is Biegel, Brown, Shapiro, and Schubert (2009) that had adolescent psychiatric outpatients going through an adapted form of MBSR. The mindfulness practices by home were shortened by 10 to 25 minutes and the day-long retreat was removed. Stress- and behavior problems related to the adolescents were in focus during presentations and discussions.

Gaps, limitations, and future directions. There have been many reviews in the latest years that have investigated the effects of meditation on the well-being of adolescents. We saw in the introduction that Waters et al. (2015) mentioned the lack of RCT and neural studies. When it comes to the former kind of studies, Evans et al. (2018) agree. They looked specifically at children with ADHD up to 18 years of age. Many studies had a high risk of bias, which they detected by using the Risk of Bias in Non-randomized Studies- of interventions (ROBINS-I) tool. Therefore they could not conclude strong enough that the interventions helped the children and they recommended future researchers to strengthen the quality of studies like this. Many others have mentioned the lack of RCT in the research field (e.g., (Felver, Celis-de Hoyos, Tezanos, & Singh, 2016), and when control groups are used, the control participants most often are passive (Semple, Droutman, & Reid, 2017).

The connection between MM and religion is also something to be aware of. Jennings (2016) discussed the relationship between church and state in the USA and its effect of implementations of what she called mindfulness awareness practices (MAP). American laws are against any religious teaching in schools. Even if there are objects and routines in meditation that can be used in both a religious and secular context, Jennings (2016) suggested avoiding misunderstandings by making these objects and routines as secular as possible.

Doing reviews of the effects of MM on adolescents is not an easy task. As in studies of adults, one problem is the lack of heterogeneity. This is because of the many variations of MM being included in the reviews, a problem that Kallapiran, Koo, Kirubakaran, and Hancock (2015) tried to control for. They compared the evaluation of studies in their review with the evaluation of studies in Zoogman, Goldberg, Hoyt, and Miller (2014). The former grouped their ”comparisons based on the type of intervention, control (active or inactive), and clinical or nonclinical population” (Kallapiran et al., 2015, *p*. 185), while the latter did no grouping of this kind. Even if this grouping was conducted, the threat of external validity based on heterogeneity still exists (Kallapiran et al., 2015). Other related problems is a lack of reports of the length of the interventions (Felver et al., 2016), and of how interventions were adapted to adolescents (Tan, 2016).

To summarize the current standings in the latest years, we look at three separate conclusions. Zoogman et al. (2014) wrote that there is no risk for general use of mindfulness in youth. The implementations of MM-programs can take place in among other schools and youth programs, and seem to support youth with mental disorders. Their final conclusion was that the more implementations of mindfulness among youth, the more possibilities of research and support for deciding which forms of mindfulness are useful (Zoogman et al., 2014). Jennings (2016) noted that the schools willing to implement meditation find more and more support from the growing research field of MAPs. In contrast, Semple et al. (2017) stated that marketing of MM programs rests on poor control of reliability and validity. Therefore we cannot yet know what programs are effective or not (Semple et al., 2017)

3. Method

A full-blown systematic review with a focus on studies on both ER and MM in both adult and adolescents would be too time and space craving. I therefore chose to limit my search based on both year of publication and cite count. The lowest amount of cites were zero for 2018-2019, ten for 2016, and five for 2017. Both newer and older studies are important, but I could not include *all* older studies since the algorithm of balancing cite counts and years used for 2016-2019 would result in too many. Therefore I chose a limit of 500 cites for the period of 2000-2009. The reason articles from 2016-2019 had such low limits is the difficulty to know how many cites they will receive the coming years. For the years 2010-2015, I chose a lowest limit of 20 cites. The cite counts were read at Google Scholar and I looked at SCImago Journal Rank H-index to evaluate the impact factor of journals. The lowest acceptable H-index was 30.

I used PubMed and Web of Science to search for abstracts. To find the articles, I used Sci-Hub and the text links at Google Scholar. The search terms were based on five study subcategories. For neural studies on MM and adults, I used “meditation neuro” and “meditation neural correlates”. I used ”emotional regulation”, ”emotion* reappraisal”, ”emotion* suppression”, and ”emotion* coping” for neural studies on ER. Before each of the four latter search terms, I added either “neuro” or “neural”. When focusing on adolescents I added “adolescen*”, “teen*”, or “you*”. For studies on adolescents and MM, the latter three terms accompanied the term “meditation”, while “neuro” and “neural correlates” was left out. Many of the MM-programs implemented in school environments include the term “mindfulness”, but not “meditation”. I therefore used “mindfulness” in relation to “adolescen*”, “teen*”, and “you*”. “Mindfulness” was not applied for adult studies, since the amount of found abstracts was too large. Last, for studies including both MM and ER, I used the four search terms related to ER and added “meditation” after each one. For adolescents, I also added the three terms related to that age group.

During the first screening process, I read the titles of the articles, and during the second screening process, I read all abstracts of all articles. If there were insufficient information in the abstracts, I read the full-text version. For adult studies, I looked after studies on MM and direct studies on ER. For adolescents, I looked after direct and indirect studies on both MM and ER. The reason for this was a hypothesized lack of studies on the effects of MM on ER in adolescents. Because of the large number of studies, this could not be done for adults. Direct studies are measurements on the effects of applying an emotional regulation strategy. In comparison, indirect studies are for example measurements of neural responses to emotional stimuli or relations between neural states or functionality and psychological measurements.

I included studies on MM where either clinical or non-clinical participants were randomized to either an experimental group or to an active or passive control group. Studies with clinical and non-clinical participants in each group, where no randomizing is possible, were also included. The forms of MM used had to be Zen, Vipassanā, or any of the secular variations. Methods that made use of cognitive or dialectical behavioral therapy were excluded. This was because the explicit focus here is on emotions and not behavior. For ER, I included studies involving either all non-clinical participants or one group with non-clinical participants and one group with clinical patients. If I found studies related to adolescents while searching for studies on adults, I included those. I did not do the reverse while searching for studies on adolescents. I also included studies that compared adolescents with ages above for the discussion about generalizing the neural responses during meditation in adults to adolescents. Further, I looked at the reference lists in my chosen articles and reviews to find more relevant articles.

For all studies, I put the lowest limit of numbers of participants included in the final analyses to 30, where both groups had to include at least 15 participants. Studies with neural measurement included fMRI, positron emission tomography (PET), and diffusion tensor imaging (DTI), while EEG was excluded. This was because of the placement of relevant brain regions, which activity EEG cannot capture. Inclusion criteria's for measured effects were emotional and cognitive-emotional effects. Studies that focused on pain, food, and sleep were excluded. So were studies on predictions of other functions than ER, cognitive consequences of ER, and effects on ER from childhood events. I further excluded studies on gender differences, and with focus on threatening, decision making and self-reference. During the investigation of results, I choose to exclude studies that involved a focus on drugs and alcohol. I also found a number of studies that I had missed during the screening process, which fell outside the inclusion criteria's. Further, I decided to include studies that measured structural brain correlates. There was one with-in study that I despite the exclusion criteria's chose to include. This was because it is the only neural study involving mindfulness and adolescents that I found. To control for the heterogeneity problem I did a similar grouping as Kallapiran et al. (2015). The first grouping was a distinction between traditional and secular forms of MM and the second grouping was a distinction between clinical and non-clinical participants.

4. Results

Table 1. Number of Received and Included Articles.

	N MM A	N ER A	N MM/ER A	MM/ER Ad	ER Ad
Received abstracts	12	88	60	74	6
Included articles	6	11	3	7	2

Note. Results organized after the five subcategories of searched articles. N = neural studies; MM = mindfulness meditation; ER = emotion regulation; A = adults; Ad = adolescents.

The five subcategories of studies included in this review are here condensed into three tables. I present adult neural meditation findings in Table 3. These findings will be used in the discussion of the generalizing of neural patterns in adult meditation to adolescent meditation. In Table 5, I compare adult and adolescent neural findings on ER and in Table 9, I compare both age groups again but for findings from the MM/ER studies. These two comparisons are the main ground for the discussion of to what extent we can generalize the effects of MM on ER in adults to adolescents. Detailed information about participants and study design in each study are presented in Table 2, 4, 5, 7, and 8. The division of conditions in design is only depicting the actual conditions, and not in the order they are conducted/presented, except when it is explicit explained. Conditions and results that are not relevant to my discussion are not reported. Functional MRI was used for measurements of brain activity, while MRI was used for measurements of white and gray matter. In the main text, the participants that went through MM-interventions are referred to as xxxx-participants (e.g., if it was an MBSR-course, they are referred to as MBSR-participants). If nothing else is stated, the control group in each study was passive.

4.1 Mindfulness Meditation in Adults

For these studies, only non-clinical participants were involved. Regions and white matter tracts with meditation-related significant short- and long-term changes are shown in Table 3. The ROIs in this summary are regions commonly associated with increased activity during both MM and ER. In addition, the ROIs for the included white matter tracts were the ones I was able to connect with significant ER-related findings. Three of the studies involved experienced Vipassanā-meditators and non-meditators. There were less spontaneous fluctuations in the default mode network (DMN) during resting state (Berkovich-Ohana, Harel, Hahamy, Arieli, & Malach, 2016) and larger concentration of gray matter in right anterior insula (Hölzel, Ott, Gard, et al., 2007) for meditators than for non-meditators. Further, it was shown that dorsomedial prefrontal cortex (dmPFC) and anterior cingulate cortex (ACC) increased more in activity during meditation than during solving an arithmetic task for all participants (Hölzel, Ott, Hempel, et al., 2007). Meditators had a larger difference in increased activity between the two conditions. In the three remaining studies, secular forms of MM were used. FEEL-meditators had a higher increase in activity in right dorsolateral prefrontal cortex (dlPFC) during meditation than non-meditators (Lutz et al., 2016). Further, the value of FA in the white matter tract corona radiata increased more after the intervention for IBMT-participants than for controls that had received relaxation training (Tang et al., 2012; Tang et al., 2010). The value of AD decreased in the same tract (Tang et al., 2012)

Table 2. Included Studies on MM in Adults

Study	Participants	Study Design
Berkovich-Ohana, Harel, Hahamy, Arieli, & Malach (2016)	Mean age: 44.2 70 % males 30 % females Ethnicity: 36 Caucasian Healthy: Non-meditators (n=18) Meditators (n=18) Meditation experience: 8,5-23,5 years of experience	Form of MM: Vipassanā. Measured variable: “the amplitude of spontan-eous fluctuations” in the brain. Measurement method: Functional MRI. Design: Only brain scanning (“In order to rule out cases of sleep or meditation practice during the resting-state, each participant was interviewed while in the scanner via an intercom with a semi structured interview”).
Hölzel, Ott, Gard, et al. (2007)	Mean age: 34.05 80 % males 20 % females Ethnicity: (n.d.a.) Healthy: Non-meditators (n=20) Meditators (n=20) Meditation experience: “2 h daily and their duration of meditation practice ranged between 2.1 years and 16.2 years”	Form of MM: Vipassanā. Measured variable: regional gray matter concentration. Measurement method: MRI (VBM). Design: Only brain scanning.

Hölzel, Ott, Hempel, et al. (2007)	Mean age: 33.6 73 % males 27 % females Ethnicity: (n.d.a.) Healthy: Non-meditators (=15) Meditators (n=15) Meditation experience: "regular meditation practice for at least two years, a daily meditation practice of 2 h, and the participation in a minimum of four 10-day courses"	Form of MM: Vipassanā. Measured variable: "the (neural) effects of the training of cognitive functions by meditation practice". Measurement method: Functional MRI. Design: 1. Meditate. 2. Solve an arithmetic task.
Lutz, Brühl, Scheerer, Jäncke, & Herwig (2016)	Age span: 28-67 55 % males 45 % females Ethnicity: (n.d.a.) Healthy: Non-meditators (nearly or completely meditation-naïve) (n=19) Meditators (n=21) Meditation experience: "at least 3 years of meditation experience with a minimum of 1 year in Vipassanā, a current practice of at least 1 h per week and retreat experience in Vipassanā (minimum duration 3 days)"	Form of MM: FEEL (mindful self-awareness). Measured variable: Neural responses. Measurement method: Functional MRI. Design: 1. Meditate (FEEL). 2. Cognitive self-reflection (THINK). 3. Rest.
Tang, Lu, Fan, Yang, & Posner (2012). Study 2 (study 1 lacked report of the number of participants in each group).	Mean age: 20.52 53 % males 47 % females Ethnicity: 68 Chinese Healthy: non-meditators that received relaxation training (RT) (n=34) meditators (n=34) Meditation experience: All of the "participants had no previous training experience and received 30 min of IBMT or RT for 2 wk, with a total of 5 h of training."	Form of MM: IBMT. Measured variable: White matter efficiency as measured by fractional anisotropy (FA), radial diffusivity (RD), and axial diffusivity (AD). Measurement method: DTI. Design: 1. DTI scan before IBMT and RT. 2. DTI scan after IBMT and RT.
Tang et al. (2010)	Mean age: 20.5 62 % males 38 % females Ethnicity: (n.d.a.) Healthy:	Form of MM: IBMT. Measured variables: fractional anisotropy (FA) + gray matter. Measurement methods:

	Non-meditators that received relaxation training (RT) (n=23) meditators (n=22) Meditation experience: All of the "participants had no previous training experience and received 30-min of IBMT or relaxation training group practice every night from Monday through Friday for 1 mo, with a total of 11 h of training."	DTI + VBM. Design: Brain scan before and after IMBT and relaxation training.

Note. n.d.a. = no data available; MRI = magnetic resonance imaging; DTI = diffusion tensor imaging; VBM = voxel-based morphometry; MM = mindfulness meditation; IBMT = Integrative body-mind training.

Table 3. Neural and Structural Effects of MM in Adults

Brain region	**Traditional MM**	**Secular MM**
DMN	V (- spontaneous fluctuations)	
R hippocampus	V (+ gm)	
R anterior insula	V (+ gm)	
R/L ACC	V (+)[a]	
R/L dmPFC	V (+)[a]	
R dlPFC		FEEL (+)
M/L frontal pole		FEEL (-)
M/L anterior cingulum		FEEL (-)
M superiror medial frontal		FEEL (-)
L inferior frontal		FEEL (-)
R cerebellum		FEEL (-)
Corpus callosum (wm)[b]		IBMT (+ FA, - AD), IBMT (+ FA)
Corona radiata (wm)[b]		IBMT (+ FA, - AD), IBMT (+ FA)
Superior longitudinal fasciculus (wm)		IBMT (+ FA, - AD), IBMT (+ FA)

Note. Each parenthesis is one specific finding concerning the listed brain regions. All regions had significant (*p* < .005) higher (+) or lower (-) (meditators>non-meditators) meditation-related spontaneous fluctuations, activity, gray matter concentration (gm), or fractional anisotropy (FA) and axial diffusivity (AD). MM = mindfulness meditation; V = Vipassanā; IBMT = integrative body-mind training; FEEL (mindful self-awareness); R = right; L = left; M = middle; DMN = default mode network; ACC = anterior cingulate cortex; dmPFC = dorsolmedial prefrontal cortex; dlPFC; dorsolateral prefrontal cortex.

[a](meditation>arithmetic task). [b]The authors of the FA-study reported changes in several specific subareas of these two regions.

4.2 Emotion Regulation in Adults and Adolescents

All included studies were comparisons between clinical and non-clinical participants. The differences in levels of brain activity and connectivity between different brain regions reported in Table 6 were correlated to the success of applying different strategies of ER. This information is used in the discussion to conclude what neural patterns during applying ER strategies there are in healthy non-clinical individuals. In three of the adult studies, there were no significant differences found. Four of the remaining studies involved depressed participants, while three studies had different focuses. The basic design was the same for most of the studies; alternating between only looking at different types of negative images and looking at them while applying an ER strategy. The ROIs for this summary were regulatory regions commonly associated with changes during ER found in both age groups and in at least two adult studies. Falquez et al. (2014) compared patients suffering from brain lesions with healthy controls. For the latter participants, gray matter intensity in left insula and middle temporal gyrus were positively correlated to their ability of self-focused reappraisal during negative stimuli. The same pattern was shown for the patients in dorsal ACC (dACC). Davis, Foland-Ross, and Gotlib (2018) had participants with and without depression decrease their affective responses while looking at negative images. In the first half of trials, dACC increased in activity for controls and decreased for participants with depression, while the latter had a larger increase of activity in dACC than controls during the second half of trials. In the third study, war veterans without post-traumatic stress disorder (PTSD) were compared to war veterans without PTSD (Rabinak et al., 2014). The latter participants had lower activity in left dlPFC while applying reappraisal during unpleasant stimuli than the former participants.

For adolescents, there were two included studies. It was shown that left anterior insula increased for depressed adolescents while playing a computer game that simulated social exclusion (Jankowski et al., 2018). In contrast, the activity decreased for non-depressed controls. For left middle temporal gyrus, the activity increased for controls during the same condition, while it decreased for depressed participants (Jankowski et al., 2018). Connolly et al. (2017) compared differences between non-depressed and depressed adolescents in functional connectivity between amygdala and other brain regions. The results showed that the former participants had higher connectivity between amygdala and left dlPFC than depressed participants.

Table 4. Included Studies on ER in Adults

Study	Participants	Study design
Davis, Foland-Ross, & Gotlib (2018)	Mean age: 33.2 100 % females Ethnicity: 23 Caucasian 7 Asian 3 Afro-American 2 Hispanic 1 mixed race Number of total participants brain scanned = 46 Analysis: Controls with "no current or past history of any Axis I disorders" (n=20) Patients (MDD) (n=16)	Measured variable: neural responses to cognitive reappraisal. Measurement method: Functional MRI. Design: 1. Look at negative and neutral images. 2. Decrease negative affect of negative images. 3. Increase negative affect of neutral images.
Falquez et al. (2014)	Mean age: 42.3 40 % males 60 % females Ethnicity: (n.d.a.) Healthy controls (n=23) Brain lesioned (predominantly affecting the frontal lobes) (n=20)	Measured variables: structural atrophies and gray matter intensities + self-focused reappraisal (REAPPself). Measurement methods: voxel-based lesion-symptom mapping (VLSM) analysis + participants ratings of the impact of negative arousal and valence[a]. Design: 1. Look at neutral and negative images. 2. Apply REAPPself when looking at negative images.
Fitzgerald et al. (2017)	(n=60) Age span: 18-65 32 % males 68 % females Ethnicity: 42 Caucasian 7 Hispanic 11 (n.d.a.) Healthy controls (n=34) Patients (GAD) (n=35) Analysis: Healthy controls (n=30) Patients (n=30)	Measured variable: neural responses to regulation of emotional reactivity Measurement method: Functional MRI. Design: Instructions in reappraisal before the experiment. 1. Look at neutral and negative images. 2. Apply reappraisal when looking at negative images.
Gaebler, Daniels, Lamke, Fydrich, & Walter (2014)	(n=44) Mean age: 30.2 33 % males 77 % females Ethnicity: (n.d.a.) Healthy controls (n=23)	Measured variable: neural responses to self-focused reappraisal. Measurement method: Functional MRI.

	Patients (SAD) (n=23) Analysis: Healthy controls (n=23) Patients (n=21)	Design: Training session on self-focused reappraisal before the experiment. 1. Look at neutral and aversive images. 2. Apply up-regulation when looking at neutral and aversive images. 3. Apply down-regulation when looking at neutral and aversive images.
Kanske, Heissler, Schönfelder, & Wessa (2012)	(n=48) Mean age: 43.7 30 % males 70 % females Ethnicity: (n.d.a.) Healthy controls (n=26) "Patients with previous episodes of major depression (MDD)" (n=26) Analysis: Healthy controls (n=25) Patients (n=23)	Measured variable: neural responses to reappraisal and distraction Measurement method: Functional MRI. Design: 1. Look at positive, neutral and negative images. 2. Apply reappraisal while looking at all images. 3. Apply distraction ("solving an arithmetic task") while looking at all images.
Kanske, Schönfelder, Forneck, & Wessa (2015). (Sample 1)	Age span: 18-65 46 % males 54 % females Ethnicity: (n.d.a.) Healthy controls (n=22) euthymic patients (bipolar-I disorder) (n=22)	Measured variables: neural responses to ER + functional connectivity. Measurement method: Functional MRI. Design: 1. Look at positive, neutral and negative images. 2. Apply downregulation while looking at all images. 3. Apply distraction ("solving an arithmetic task") while looking at all images.
Rabinak et al. (2014)	Mean age: 32.5 100 % males Ethnicity: 38 Caucasian 2 Afro-American 1 Hispanic/Latino 1 Asian Veterans from the wars in Afghanistan or Iraq: without PTSD (n=21) with PTSD (n=21) Note: Participants with alcohol abuse (n=1)	Measured variable: neural responses to cognitive reappraisal. Measurement method: Functional MRI. Design: 1. Look at neutral images 2. Look at unpleasant images 3. Apply reappraisal while looking at unpleasant images.
Radke et al. (2018)	Mean age: 33.5 59 % males	Measured variable: "up- and down-regulation in response to

	41 % females Ethnicity: (n.d.a.) Healthy controls (n=22) Patients (MDD) (n=22)	angry facial expressions". Measurement method: Functional MRI. Design: 1. Look at neutral and angry faces in images. 2. Apply up-regulation while looking at neutral and angry faces in images. 3. Apply down-regulation while looking at neutral and angry faces in images.
Richey et al. (2015)	Mean age: 26.7 87 % males 13 % females Ethnicity: (n.d.a.) Controls (n=15) Autistic (n=15)	Measured variable: neural responses during cognitive reappraisal Measurement method: Functional MRI. Design: Training sessions on cognitive appraisal before the experiment. 1. Look at neutral faces in images. 2. Think positive while looking at the images. 3. Think negative while looking at the images.
Smoski, Keng, Schiller, Minkel, & Dichter (2013)	Mean age: 26.2 30 % males 70 % females Ethnicity: 29 Caucasian 5 Hispanic 4 African 3 Asian 1 American-indian Healthy controls (n=19) Patients (rMDD) (n=18)	Measured variable: "neural mechanisms of emotion regulation in" rMDD. Measurement method: Functional MRI Design: 1. Look at sad and neutral images 2. Apply reappraisal while looking at sad images.
Tozzi et al. (2017)	(n=69) Mean age: 31.6 35 % males 65 % females Ethnicity: (n.d.a.) Number of total participants recruited: n=79 Analysis: Controls (n=35) Patients (MDD) (n=34)	Measured variables: neural responses to voluntary attentional regulation + functional connectivity. Measurement method: Functional MRI. Design: Look at positive, neutral, or negative images and being asked about either the emotional valence of the image or about the orientation of it.

Note. If there were drop outs, excessive motion, or technical difficulties after or during the brain scans, the number of participants both scanned and in the final analysis are reported. If "(n=xx)" is included in the presentation of demographic information, it means that the information refers to the participants included in the final analysis. n.d.a. = no data available; ER = emotion regulation; MDD = major depressive disorder; SAD = social anxiety disorder; GAD = general anxiety disorder; PTSD = posttraumatic stress disorder; rMDD = remitted major depressive disorder; MRI = magnetic resonance imaging.

[a]Emotional measurements are included because they were crucial in the report of results.

Table 5. Included Studies on ER in Adolescents

Study	Participants	Design
Connolly et al. (2017)	(n=101) Mean age: 16.1 39 % males 61 % females Ethtnicity: (n.d.a) Healthy controls (n=77) Patients (MDD) (n=66) Analysis: Healthy controls (n=53) Patients (n=48)	Measured variables: "amygdala resting-state functional connectivity (RSFC)" + depression, anxiety. Measurement methods: Functional MRI + Children's Depression Rating Scale-Revised (CDRS-R), Reynolds Adolescent Depression Scale (RADS-2), Multidimensional Anxiety Scale for Children (MASC). Data were collected before brain scans and at a three-month follow up.
Jankowski et al. (2018)	(n=126) Mean age: 14.6 44 % males 56 % females Ethnicity: 78 Caucasian 12 Hispanic 11 Afro-american 1 American-indian 15 multiethnic 4 other Number of total participants recruited: n=134 Analysis: Healthy controls (n=39) Patients (depression) (n=87)	Measured variable: neural responses to social exclusion. Measurement method: Functional MRI. Design: The participants played a computer game (Cyberball), where they were told that they were playing against real persons. The game alters between simulating social excluding and social including.

Note. (n=xx) in the presentation of demographic information refer to the participants included in the final analysis. n.d.a. = no data available. MDD = major depressive disorder; MRI = magnetic resonance imaging.

Table 6. Direct and Indirect Neural and Structural Correlates of ER

Brain region	Adults	Adolescents
L anterior insula		1 (+)
L insula	(gm)[a]	
Superior frontal gyrus	(gm)[b]	
L inferior frontal gyrus		1 (+)
Middle temporal gyrus	(gm)[a]	
L middle temporal gyrus		1 (-)
dlPFC	(gm)[b]	
L dlPFC	(-)[e]	1 (- Co)
L vmPFC		1 (- Co)
L dmPFC	1 (+)	
sgACC	1 (-)	
PCC	1 (-)	
dACC	1[c], (gm)[b]	
SMA	1[c]	
R superior frontal gyrus	(gm)[a]	
Basal ganglia	(gm)[a]	
B cerebellum	(gm)[a]	
L amygdala	1 (+), X (+)[d]	
R amygdala	(+)[d]	
OFC	(Co)[d]	
R OFC	1 (+)	
R parahippocampus	(+)[d]	
R posterior medial frontal cortex	1 (+)	
L fusiform gyrus	1 (+)	
L supramarginal gyrus	1 (+)	
L superior temporal gyrus	1 (+)	
R middle frontal gyrus	1 (-)	

Note. Each parenthesis is one specific finding concerning the listed brain regions. The two findings without parenthesis are explained below. For each study, if not specified in the notations, patients are compared against controls. All regions had significant ($p < .005$) higher (+) or lower (+) emotion regulation-related activity, gray matter concentration (gm), or connectivity with amygdala (Co). Notation *a* and *b* concern the same study. 1 = participants with previous or current episodes of depression; R = right; L = left; B = bilateral; dlPFC = dorsolateral prefrontal cortex; vmPFC = ventromedial prefrontal cortex; dmPFC = dorsomedial prefrontal cortex; sgACC = subgenual anterior cingulate cortex; dACC = dorsal anterior cingulate cortex; PCC = posterior cingulate cortex; SMA = supplementary motor area; OFC = orbital frontal cortex.

[a]Regions where gm intensity positively correlated to arousal-related scores in self-focused reappraisal for controls. [b]Regions where gm intensity was associated with arousal-related scores in self-focused reappraisal for brain lesioned. [c]In early trials, dACC increased for controls and decreased, together with SMA, for patients. Controls had smaller SMA decrease than patients. In late trials, patients had a larger increase

in dACC than controls. SMA decreased for controls but increased for patients. [d]Bipolar 1-patients>controls. Patients had positive connectivity between OFC and amygdala, while controls had negative connectivity. [e]War veterans with posttraumatic stress disorder (PTSD) > war veterans without PTSD.

4.3 The Effects of Mindfulness Meditation on Emotion Regulation in Adults and Adolescents

Secular forms of MM were used in all included studies. The three adult studies involved non-clinical participants, while four studies on adolescents involved participants with psychiatric diagnoses or mental health problems. The remaining two adolescent studies involved healthy non-clinical students from schools. In three of the neural adult studies, brain activity was measured while participants expected or looked at negative stimuli. In the fourth study, an affective Stroop task was used as stimuli. The ROIs for this summary were regulatory regions commonly associated with changes during ER found in at least two studies and in the only neural/psychological study. The affective Stroop task-study involved participants from a six-week MM-course, including focused attention and open monitoring, and controls that participated in group reading sessions (Allen et al., 2012). Results showed that the former participants had higher activity in left dlPFC during the task than the group reading participants. Lutz et al. (2013) included participants within a range from no earlier MM-experience to currently practicing MM in their experiment. Both groups looked at positive, neutral, and negative images but only the experimental group was allowed to meditate during these conditions. In addition, a cue of what valence the upcoming image would have was presented during every trial. It was shown that left dlPFC increased more in activity during the expectation of negative images for meditators than for controls (Lutz et al., 2013). Farb et al. (2010) had MBSR-participants and controls watch neutral or sad movie clips. The former participants had higher activity in right insula and lateral PFC than controls while watching the sad movie clips. The activity of left lateral PFC during the same condition was lower for the MBSR-participants. In addition, scores of depression and anxiety decreased after the intervention (Farb et al., 2010).

For adolescents, there were three studies that used adapted forms of MBSR (aMBSR). The two first presented studies involved adolescents with psychiatric diagnoses. Biegel et al. (2009) found that aMBSR-participants had lower scores on stress, anxiety, and depression than controls. The aMBSR-participants in the second study had higher mindfulness scores compared to controls (Brown, West, Loverich, & Biegel, 2011). It was also shown that increases in mindfulness were correlated to decreases in stress and past anxiety. In the third study, where adolescents with mental health problems were involved, the scores of 'internalizing problems' were higher for controls than for aMBSR-participants (Vohra et al., 2019). For the remaining three adolescent studies, a variety of secular forms of MM were used. Results from the two studies with students showed that MM-participants had lower scores on 'acting with awareness' (Johnson, Burke, Brinkman, & Wade, 2017) and depression (Raes, Griffith, Van der Gucht, & Williams, 2014). To conclude, Tan and Martin (2015) found that adolescents with psychiatric diagnoses that completed the MM-intervention had higher scores on mindfulness and lower scores on depression, anxiety, and stress than controls.

Table 7. Included Studies on the Effects of MM on ER in Adults

Study	Participants	Design
Allen et al. (2012)	Ethnicity: (n.d.a.) Control (group reading) (n=31) Meditation (n=30) Mean age: 26,5 Males/females[a] Analysis:[b] Controls (n=19, 10 females) Meditators (n=19, 11 females) Meditation experience: none	Form of MM: A 6 week-course including focused attention and open monitoring. Measured variable: neural responses during an affective Stroop task. Measurement method: Functional MRI. Design: 1. Training session. 2. Brain scan while performing a number-counting Stroop task with congruent and incongruent trials where positive, neutral, and negative images were used as distractors (no meditation). The task were performed before and after the interventions.
Farb et al. (2010)	Mean age: 43.7 25 % males 75 % females Ethnicity: (n.d.a.) Controls (waitlist) (n=16) Meditators (n=20) Meditation experience: (n.d.a.)	Form of MM: MBSR Measured variables: neural responses to sadness provocation + depression, anxiety, sadness. Measurement methods: Functional MRI + The Beck

		Depression Inventory–Second Edition (BDI–II), The Beck Anxiety Inventory (BAI), 5-point Likert scale. Design: Watch neutral or sad movie clips with audio during brain scan. Data collected at pre-intervention for both groups and at post-intervention for meditators.
Lutz et al. (2013)	(n=46)[c] Age span: 20-57 48 % males 52 % females Ethnicity: (n.d.a.) Healthy: Controls (n=23) Meditators (n=26) Analysis: Controls (n=22) Meditators (n=24) Meditation or meditation related experience for the meditators: No experience n=9 Earlier experience n=17 Currently practicing n=4	Form of MM: ”Do not judge; remain conscious and attentive to your present state. You may focus on thoughts, on emotions or on bodily sensations.” (MM were only practiced during the experiment). Measured variable: Neural responses to MM during expectation and perception of emotional stimuli. Measurement method: Functional MRI. Design: emotional expectation paradigm. 1. Training session. 2. A cue of the valence (positive/neutral/negative) before the image appeared. 3. A cue that could mean both a pleasant and an unpleasant image. 4. Baseline period (meditation only allowed during 1 and presentation of unpleasant images).

Note. The division of conditions in design is only depicting the actual conditions, and not in the order they are conducted/presented, except when it is explicit explained. Conditions that are not relevant for my discussion are not reported. If there were drop outs, excessive motion, or technical difficulties after or during the brain scans, the number of participants both scanned and in the final analysis are reported. n.d.a. = no data available.

[a]Number of males and females were no reported. [b]Age span or mean age were not reported. [c]The demographic information refer to the participants included in the final analysis.

Table 8. Included Studies on the Effects of MM on ER for Adolescents

Study	Participants	Design
Biegel, Brown, Shapiro, & Schubert (2009)	(n=102) Age span: 14-18 27 % males 73 % females Ethnicity: 46 Caucasian 29 Hispanic/ Latino 3 Afro- American 17 mixed 7 other Participants with "heterogeneous diagnoses in an outpatient psychiatric facility": TAU (n=46) MBSR + TAU (n=39) Analysis: TAU (n=40) MBSR + TAU (n=34)	Form of MM: adapted MBSR. Measured variables: stress, anxiety, depression. Measurement methods: PSS-10, STAI, Hopkins Symptom Checklist 90 (Revised) non patient adolescent measure (SCL-90-R). Data collected at pre-intervention, post-intervention, and at a 3-month follow up.
Brown, West, Loverich, & Biegel (2011) (Study 2)	Age span: 14-18 26 % males 73 % females Ethnicity: 46 Caucasian 29 Hispanic/Latino/ Latina 17 mixed 6 Asian 3 Afro-American 1 native American Patients from an "outpatient Child and Adolescent Psychiatry Department": TAU (n=52) TAU + MBSR (n=50) Note: "Seventy-four participants completed assessments at all three time points"	Form of MM: Adapted MBSR Measured variables: mindfulness, stress, anxiety as a state and as a trait. Measurement methods: Mindful Attention Awareness Scale for Adolescents (MAAS-A), PSS-10, STAI. Data collected at pre-intervention, post-intervention, and a 3-month follow up.
Johnson, Burke, Brinkman, & Wade (2017)	(n=555)[a] Mean age: 13.44 55,6 % males 45,4 % females Ethnicity: (n.d.a.) Participants from four urban coeducational secondary schools: Controls (n=178) Meditators (n=186)	Form of MM: The *.b* ("Dot be") Mindfulness in Schools curriculum. Measured variables: mindfulness, depression, anxiety, stress, well-being, emotional dysregulation. Measurement methods: DASS-21, Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS), Comprehensive Inventory of Mindfulness Experiences –

	Post-intervention: Controls (n=154) Meditators (n=156)	Adolescents (CHIME-A). Data collected at 3–4 weeks pre-intervention, post-intervention, and 6- and 12-month follow-up.
Raes, Griffith, Van der Gucht, & Williams (2014)	(n=393)[b] Age span: 13-20 36 % males 64 % females Ethnicity: (n.d.a.) Participants from five schools: Controls (n=206) Meditators (n=197) Post-intervention: Controls (n=185) Meditators (n=185) 6-month follow up: Controls (n=175) Meditators (n=170)	Form of MM: "mindfulness group training specifically developed for adolescents " (MGT). Measured variable: depression. Measurement method: DASS-21. Data collected at pre-intervention, post-intervention, and 6-month follow up.
Tan & Martin (2015)	Age span: 13-18 25 % males 75 % females Ethnicity: (n.d.a.) Patients with primary psychiatric diagnoses, without prior mindfulness training: TAU (n=43) TAU + TAM (n=43) Analysis: TAU (n=37) TAU + TAM (n=43)	Form of MM: Taming the adolescent mind (TAM). Measured variables: mindfulness, depression, anxiety, stress. Measurement methods: CAMM, DASS-21. Data collected at pre-intervention, post-intervention, and 3-month follow up.
Vohra et al. (2019)	Age span: 12-18 59 % males 41 % females Ethnicity: 59 white/Caucasian 22 other Participants were "residents of CASA House, a voluntary residential treatment program for adolescents": TAU (n=39) TAU + MBSR (n=42)	Form of MM: adapted MBSR. Measured variables: mindfulness, stress, emotional regulation, "Internalizing problems" (anxiety, depression, somatization, atypicality, and withdrawal). Measurement methods: CAMM, PSS, Emotional Regulation Questionnaire (ERQ), Behavior Assessment System for Children, Second Edition (BASC-2). Data collected at pre-intervention, post-intervention, and a 3-month follow up.

Note. If there were drop outs after the completed MM-intervention, the number of participants both completing the intervention and in the final analysis are reported. The number of analyses included is governed by the number of analysis included in the relevant results. If "(n=xx)" is included in the presentation of demographic information, the information refer to the participants included in the final analysis. n.d.a. = no data available; MM = mindfulness meditation; TAU = treatment as usual; MBSR = mindfulness-based stress reduction; PSS-10 = 10-item Perceived Stress Scale; STAI = State-Trait Anxiety Inventory; DASS-21 = 21-item Depression Anxiety Stress Scale; CAMM = Children's Acceptance and Mindfulness Measure

[a]One group were excluded because of non-relevance for this review. [b]Not all participants included in the demographic information.

Table 9. Indirect Neural and Psychological Effects of MM on ER

Brain region	**Adults**	**Psychological effects**	**Adults**	**Adolescents**
L dlPFC	O (+)[a], O (+)[b]	Reduced conflict during an affective Stroop task	O[b]	
DmPFC	O (+)[a]	Depression	M (-)[c]	aM (-), O (-), O (-)
L anterior insula	O (+)[a]	Anxiety	M (-)[c]	aM (-), O (-)
R insula	M (+)[c]	Stress		aM (-), O (-)
R lateral PFC	M (+)[c]	Mindfulness		aM (+), O (+)
R sgACC	M (+)[c]	"acting with awareness" in CHIME-A		O (-)
R gyrus rectus	M (+)[c]	"internalizing problems" in BASC-2		aM (-)
L thalamus	M (+)[c]			
L superior temporal sulcus	M (-)[c]			
L lateral PFC	M (-)[c]			
L middle temporal gyris	M (-)[c]			
R precuneus	M (-)[c]			
R amygdala	O (-)[d]			

Note. Each parenthesis is one specific finding concerning the listed brain regions and psychological effects. Brain regions were only investigated in adult studies. All regions and psychological measurements had significant ($p < .005$) changes (meditators>controls) in activity and scores. The specific conditions for each adult study are presented below. Adolescents filled in questionnaires before and after the MM-interventions. + = higher activity/scores; - = lower activity/scores; M = MBSR; aM = adapted MBSR; O = other secular forms of MM; CHIME-A = Comprehensive Inventory of Mindfulness Experiences – Adolescents; BASC-2 = Behavior Assessment System for Children, Second Edition. R = right; L = left; M = middle; dlPFC = dorsolateral prefrontal cortex; dmPFC = dorsomedial prefrontal cortex; sgACC =

subgenual anterior cingulate cortex.
[a]Expectation of negative images. [b]The reduced reflex time for meditators were followed by increased activity in left dlPFC. [c]Sadness provocation. [d]Perception of negative images.

In a correlational with-in study not reported in any table, Marusak et al. (2018) looked at neural connectivity and psychological variables in children and adolescents aged 6-17. For the psychological variables, it was shown that higher levels of mindfulness were related to lower levels of anxiety. There were five connectivity states found in the study that were too detailed to include them all here. Participants with higher levels of mindfulness remained in each state for a shorter time than the participants with lower levels. The state that former participants spent the shortest time in involved the default mode network (DMN), the central executive network (CEN), and the salience and emotion network (SEN). DMN is activated during mind-wandering and self-referential processes, CEN during attentional processes, and SEN during being present in the moment. The state was described as “positive DMN connectivity with left and right CEN components, positive connectivity between left and right CEN, negative SEN connectivity with left and right CEN, and negative DMN-SEN connectivity” (Marusak et al., 2018, p 213).

5. Discussion

My first aim was to investigate the neural effects of MM on ER in adults. To reach a conclusion, I will first go through adult studies on MM, ER and MM/ER. The two latter sections include direct comparisons to results from adolescents. This lays the ground for the discussion of my second aim; if we can generalize the neural effects of MM on ER in adults to adolescents.

When it comes to the conceptual debate in this research field, one must first realize that there are different forms of both MM and ER. There is also an overlap between the two separate concepts and the relationship between them can be seen from two perspectives. The first perspective is to see it as a causal progress, where MM in the long term strengthens the activity in ER-related regions. This in turn strengthens the ability of ER. The other perspective is to see MM as a subgroup of ER. One ER-related finding in the included MM-studies was the increase of FA in corona radiata for IBMT-meditators (Tang et al., 2012; Tang et al., 2010). It has been shown that this white matter tract had a larger value of FA in participants that were faster at resolving conflicts than controls (Niogi, Mukherjee, Ghajar, & McCandliss, 2010). This is in accordance with the frontal location of the tract (Yin et al., 2011). This is also an argument for both perspectives. Because this lays beyond the main focus of this review, I leave this specific discussion for future debates.

5.1 Mindfulness Meditation

There were no similar findings between traditional and secular forms of MM. If we zoom out from the specific brain regions reported, there were overlapping regions found in the studies with Vipassanā-meditators. Berkovich-Ohana et al. (2016) reported less spontaneous fluctuations in the default mode network (DMN) during resting state for meditators. This network is located in PFC and parietal cortex and is most active during rest (Hafkemeijer, van der Grond, & Rombouts, 2012). One of the subregions is dmPFC, which had a higher increase in activity during meditation for meditators (Hölzel, Ott, Hempel, et al., 2007). The question is how lower spontaneous fluctuations and increased brain activity are related to each other. I did not find any clear explanation of this in the study conducted by Berkovich et al. (2016). However, based on earlier findings they suggested that the low spontaneous fluctuations in the meditators are associated with less engagement of thinking of past and future events and a larger attentional readiness than non-meditators. In addition to the increase of activity in dmPFC, ACC also had a larger increase for meditators (Hölzel, Ott, Hempel, et al., 2007). Both regions have been shown to increase in activity during the application of ER strategies (Falquez et al., 2014; Kanske et al., 2012). This is also the case for the meditation-related increase of activity in right dlPFC (Lutz et al., 2016; Falquez et al., 2014). The finding of the higher gray matter intensity in right anterior insula for Vipassanā-meditators (Hölzel, Ott, Gard, et al., 2007) is in line with MBSR-meditators showing higher activity in right insula during sadness provocation than non-meditators (Farb et al., 2010). When it comes to the smaller increase for Vipassanā-meditators in middle superior medial frontal gyrus (only reported in Table 3) (Lutz et al., 2016), this finding stands in contrast with an earlier finding. Goldberg, Harel, and Malach (2006) observed a positive correlation between the level of self-awareness and the level of activity in superior frontal gyrus. Based on this study, one would instead conclude that meditators had higher activity in the region. To conclude, the observations that corona radiata increased in FA and decreased in AD (Tang et al., 2012; Tang et al., 2010) for IMBT-meditators does not imply conflicting results. This inverse relation was discussed further by Tang et al. (2012).

5.2 Emotion Regulation

ROIs for between-group similarities and differences were anterior insula, left dlPFC, and middle temporal gyrus. Left anterior insula increased in activity for adolescents with depression during social exclusion, while it decreased for controls (Jankowski et al., 2018). For adult controls, gray matter intensity in left insula positively correlated to scores in arousal-related self-focused reappraisal (Falquez et al., 2014). Depression has often been associated with anterior insula (e.g., Avery et al., 2014) and the larger effect of social exclusion in depression might be an indirect effect of impaired ER. What makes this problematic is that the results of another study showed increased insular activity during social exclusion in participants *without* depression (Eisenberger, 2003). Arousal and insular cortex have also been associated before (e.g., Singer, Critchley, & Preuschoff, 2009). While Falquez et al. (2014) suggested that insular cortex is involved in down-regulation, Grecucci, Giorgetta, Bonini, and Sanfey (2013) observed increased insular activity during up-regulation. A later study supported the role of insular cortex in down-regulation (Steward et al., 2016).

Left dlPFC increased more in activity for war veterans without PTSD during reappraisal than for veterans with PTSD (Rabinak et al., 2014) while non-depressed adolescents had higher connectivity between left dlPFC and amygdala than depressed adolescents (Connolly et al., 2017). The explanation of the former result is likely that PTSD is associated with disabilities in ER (e.g., Ehring & Quack, 2010). In what seems like a contrast, results have shown that the severity of PTSD is positively correlated to the use of ER strategies, reappraisal included (Tull, Berghoff, Wheeless, Cohen, & Gratz, 2018). When looking superficially at these two statements, the most likely explanation is that there is a difference between the ability of ER and how often one *uses* ER strategies. Regarding the study on depression, the level of left dlPFC- and amygdala connectivity have earlier been shown to be positively correlated to ER ability (e.g., Banks, Eddy, Angstadt, Nathan, & Phan, 2007). In addition, it has many times been shown that depression is associated with impaired ER (e.g., Joormann & Gotlib, 2010).

The intensity of gray matter in middle temporal gyrus for healthy non-clinical adults was positively correlated to arousal-related scores in self-focused reappraisal (Falquez et al., 2014). For depressed adolescents, the left middle temporal gyrus decreased in activity during social exclusion (Jankowski et al., 2018). This region has been associated with ER in other studies (e.g., Ochsner et al., 2004). The current uncertainty of the relationship between social exclusion, depression and neural responses makes it difficult to explicitly state that these two studies are in accordance with each other. When it comes to the insular cortex and middle temporal gyrus, it is difficult to compare the neural responses between age groups due to the contradictory findings. The insular cortex seems to play a role in ER, but from my limited research on this matter, I can't say what kind of role it has. The same problem concerns middle temporal gyrus. For dlPFC, the two age groups follow the same pattern; higher connectivity to amygdala and higher activity is associated with stronger ER.

5.3 Emotion Regulation and Mindfulness Meditation

The similarity in findings between clinical and non-clinical adolescents was lower scores of depression after the MM-interventions (Biegel et al., 2009; Raes et al., 2014; Tan & Martin, 2015). For the latter, stress, anxiety (Biegel et al., 2009; Tan & Martin, 2015), and the scores of ‘internalizing problems’ (Vohra et al., 2019) decreased, and results from Brown et al. (2011) showed that increases in mindfulness was correlated to decreases in stress and past anxiety. In one study involving non-clinical healthy participants, “acting with awareness” was significantly lower for meditators compared to non-meditators at post-intervention (Johnson et al., 2017). Higher scores mean acting with more awareness. In contrast, clinical adolescents had higher scores on mindfulness after interventions (Brown et al., 2011; Tan & Martin, 2015). The reason for this difference could lay in the definitions of “mindfulness” and “acting with awareness”. Could it be that one becomes more mindful of one’s own emotions, thoughts, and body sensations, with the consequence that one becomes less aware of the outside world? This would be reasonable if MM did not include also awareness of sensory perceptions. Further, the MM-program in this study included “...mindfulness of routine daily activities including walking ...“(Johnson et al., 2017, p 38). When it comes to the study on neural connectivity states (Marusak et al., 2018), children and adolescents with higher levels of mindfulness spent the shortest time in the state where DMN and CEN were positively connected. This is in accordance with an adult study where both those regions were activated during mind-wandering (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009). In addition, the pattern of increased mindfulness and decreased anxiety was also observed in Marusak et al. (2018)

Adult MBSR-meditators also showed reductions in depression and anxiety after the intervention (Farb et al., 2010). The same study reported higher activity in right insula and lateral PFC for meditators during sadness provocation. In addition, there was a decrease in left lateral PFC. The two first findings are in line with other findings in this review; Right anterior insula and dlPFC showed meditation-related increases in adult MM-studies (Hölzel, Ott, Gard, et al., 2007; Lutz et al., 2016). The decrease of activity in left lateral PFC (Farb et al., 2010) stands in contrast with Rabinak et al. (2014) that in their ER-study found increased activity in left dlPFC during reappraisal. The difference between the two studies was that the latter used unpleasant images as stimuli and had a focus on the dorsal region. There are two included MM/ER findings of higher left dlPFC activity for meditators that support Rabinak et al. (2014); Allen et al. (2012) used an affective Stroop task as stimuli, while Lutz et al. (2013) measured activity during the expectation of negative stimuli.

5.4 Generalizing Results From Adults to Adolescents

My first aim was to investigate the neural effects of MM on ER in adults. I give summarizes of each adult subcategories along this section and save the conclusion for section 5.7. My second aim with this thesis was to investigate to what extent we can generalize the neural effects of MM on ER in adults to adolescents. To search for answers I first compare findings from the included ER-studies. Based on the earlier discussion of ROIs from these studies, the only region involved in ER with a similar pattern for both age groups is dlPFC. The question is if there is a difference between the groups when it comes to the amplitude of signal changes during ER. Due to the difference in measurements, a comparison like this is not possible. This problem concerns also the other ROIs from the included ER studies. What about neural responses of MM in adolescents? For non-clinical adults, there was a positive correlation between practicing meditation and the level of increased activity in dmPFC, ACC (Hölzel, Ott, Hempel, et al., 2007), and dlPFC (Lutz et al., 2016). Further, Vipassanā-meditators had greater gray matter concentration in right anterior insula (Hölzel, Ott, Gard, et al., 2007) and higher value of FA in corona radiata (Tang et al., 2012; Tang et al., 2010) than controls. Can we generalize these neural patterns to adolescents? To be able to speculate around this question, I need to take developmental studies into account. These studies were found after my systematic search and had no inclusion- or exclusion criteria's bound to them. To start with, the last brain regions to mature during adolescence, based on measurements of gray matter concentration, is among others the regulatory regions (Gogtay et al., 2004). This pattern for the regulatory regions was also shown for the synaptic plasticity during adolescence, where there is a large elimination process of unused synapses (Selemon, 2013). Further, results from children and adolescents (Silvers et al., 2017) showed that ventromedial PFC activation to aversive stimuli is negatively correlated to age. Activation of dmPFC showed the opposite relation (Silvers et al., 2017). If combining these three studies, it seems like greater functioning in dmPFC is correlated to changes in gray matter concentration and elimination of unused synapses.

Even if Silvers et al. (2017) is not included in the systematic findings, their results are important for my discussion. It suggests an answer about the difference in amplitude of activity while applying ER strategies between age groups; that dmPFC increases more for adults than for adolescents. This implies that the neural patterns shown in adult meditation cannot be generalized to adolescents; if the functioning of dmPFC is different during ER for adolescents compared to adults, it should also be different during MM. This leads to many questions that are difficult to answer based on the limited observations I have made. For example, does better functioning of dmPFC during ER over time mean that it reacts better to MM over time? If one would start practicing MM in early adolescence, would that strengthen the functioning of dmPFC in the long-term? One reason of the difficulty in answering these questions lies in the not yet answered question about the overlap between the two concepts of MM and ER.

If we return to the included adult ER-studies, we could see that higher ability of ER was associated with greater functioning in dACC (Davis et al., 2018; Falquez et al., 2014). Can the developmental studies answer if this neural pattern can be generalized to adolescents? I found an interesting observation made in a review conducted by Casey, Jones, and Hare (2008). They concluded that even if children use distinct PFC regions during cognitive tasks, these regions are in general more diffuse and larger than in adults (Casey et al., 2008). The problem with this observation is what to make of it. If the regions really are diffuse, this does not imply any straightforward correlations with the amplitude of activity. One correlation that is easier to suggest is that the more diffused regions, the less functional they are.

For the included MM/ER studies, the only similarity in findings between age groups was the reduction of anxiety and depression after MM interventions. How well can this observation help us understand the neural responses in adolescents? One way to investigate this would have been to compare effect sizes and used these measurements as a proxy for the neural responses. Due to the low amount of included studies, this was not possible. There would also have brought back the problems with doing so discussed by Kanske et al. (2012) and Davidson and Kaszniak (2015). When it comes to the neural observations in adult studies, there were higher activity during emotional stimuli for meditators in dmPFC, left anterior insula and dlPFC (Lutz et al., 2013), and in right insula, lateral PFC and subgenual ACC (Farb et al., 2010). The already discussed developmental studies give no clear answers if these results can be generalized to adolescents. What I *can* do, is to carefully confirm earlier conclusions from this research field; the practice of MM strengthens the ability of ER over time in both adults and adolescents. What I *cannot* conclude is to what extent we can generalize the neural effects of MM on ER in adults to adolescents. Even if I take the not included study made by Silvers et al. (2017) into account, I cannot make any clear conclusions. The only thing that we learn from that study is that there *are* neural differences between adults and adolescents. This was already well known before I chose to conduct this review.

5.5 Limitations in the Included Studies and Future Directions

What neural differences there are between adults and adolescents when it comes to the effect of MM on ER is for future and carefully conducted research to investigate. As the research field looks now, there is a need for improvements. First, many studies did not report ethnicity, which is important for cultural differences. Second, the majority of studies where the experimental group went through MM-interventions had passive control groups. Two studies with active controls had them go through relaxation training instead of an MM-intervention (Tang et al., 2012; Tang et al., 2010). This setup can be questioned on the ground of the closeness of meditation and relaxation. There are also some specific studies that need to be highlighted. Firstly, the “non-meditators” in Lutz et al. (2016) were reported as “nearly or completely meditation-naïve” (p. 22). Secondly, Farb et al. (2010) had data on psychological measurements collected at post-intervention for meditators, while there were no data collected for the control group during the same point in time. I still included this study because of the likelihood of there being a group difference if data on controls also had been collected. This decision was based on the high number of significant group differences reported in other studies.

Based on these limitations, my general suggestions for future researchers are to use active control groups and to collect data on ethnicity. Further, the studies on psychological measurements need to continue and support neural studies. Even if there are problems with using these measurements as a proxy for neural responses, these measurements *are* important. For example, Zenner, Herrnleben-Kurz, and Walach (2014) conducted a systematic review and a meta-analysis on mindful-based interventions in schools. When including all reviewed studies and all measured effects, they found a medium effect size of g = 0,4. They compared their finding with other meta-analysis and found effect sizes of d = 0,5 for MBSR involving clinical and non-clinical adult participants (Grossman, Niemann, Schmidt, & Walach, 2004), and of r = 0,31 for MBSR involving only non-clinical adult participants (Eberth & Sedlmeier, 2012). Based on these effect sizes, Zenner et al. (2014) suggested that mindful-based interventions are more effective for non-clinical adults than for non-clinical younger participants.

Firstly, the problem with comparing Zenner et al. (2014) with this review is that they looked at a wide spectrum of variables while I looked only at ER. Despite this difference, findings like these are still interesting and should be acknowledged when conducting the needed neural studies on MM for adolescents. Secondly, these studies take us back to the motivational force behind my systematic review; the discussion of what forms of MM are most effective to increase the ability to regulate emotions in adolescence. What contributions can my thesis bring to this discussion? The research field of MM and adolescents is growing but the included studies in my review did not have a direct focus on ER. Instead they indirectly measured ER, through measurements of emotional states and personality traits. I think many researchers can agree on the importance of the ability to regulate one’s emotions in developing a healthy emotional life. I therefore hope that my thesis can inspire others to conduct more direct research on the effects of MM on ER for adolescents. As others have stated, there are conceptual debates about MM, ER, and the difference between them. This debate is intertwined in the question of what neural regions are activated in each strategy of ER and each type of MM. Even if knowledge of the neural effects of both MM and ER is in the background when researchers look at the effect of MM on ER, I directly compare them in my thesis. I have seen only one article having a similar approach regarding neural overlaps between MM and ER. Since this comparison is a valuable perspective to have in my chosen particular research field, both to try to resolve conceptual and neural questions, I hope to see more similar studies as mine. What I cannot contribute with is to answer what actually *are* the most effective forms of MM to increase adolescent's ability of ER. For that, I suggest to continue the neural research of ER in adolescents and start conducting neural studies on MM. If we knew the neural responses of both MM and ER in adolescents, separately, we could see the relationship between them clearer. This would allow for more constructive MM/ER-studies. These suggestions also concern my second aim; to investigate the neural differences between adults and adolescents.

5.6 Limitations in the Current Review

Maybe the largest limitation with this study is the lack of a clear definition of what "to what extent" in my second aim means. If I have had prechosen alternatives of possible levels of differences, my discussion and conclusions could have been stronger. Another large limitation was the heterogeneity problem. Before my conducted systematic search, I chose to differentiate between traditional and secular forms of MM and between non-clinical and clinical participants for both age groups. Because all included MM/ER-studies used secular forms of MM and the low amount of included adult MM-studies, this differentiation gave no reduction of the problem. This conclusion also concerns comparing clinical and non-clinical participants since there were only non-clinical participants in the included MM- and MM/ER-studies on adults and too few similar findings for adolescents. If we add the conceptual problems with ER and MM, the heterogeneity problems become even larger. In hindsight, I should have differed between the forms of secular MM instead. Further, the inclusion of cite limits could result in bias and should have been avoided. If I had done that, I would instead have shortened the included year span to avoid too many included articles. One problem that could *not* be avoided was that I was alone in conducting this systematic review, which opens up for biased decisions.

There are two main steps in comparing neural responses between adults and adolescents during the application of ER for meditators; to know what brain regions are commonly activated in both age groups and to compare the effects sizes in the neural changes for each region. To do this comparison for the included ER studies would have given us a clue of what difference in effect MM would have on ER between the two age groups. Because there was not a single specific region that was reported in both age groups with the same measurement method, I could not do this. Another way would have been to compare the effect sizes of improved psychological variables due to meditation between the groups. The variables would then have been seen as a possible proxy for the neural responses. This could also not be done, because there was only one adult study for each variable. If it had been applicable, I could still not come to any strong conclusions because of the problems with using these variables as a proxy. I could have included within-group design when looking at studies on solely the neural effects of ER. This is because ER studies often do not include interventions prior to the actual experiment. The decision to look at only between-group studies resulted only in comparisons between clinical and non-clinical participants. These comparisons are useful for the investigation of what regions are responsible for ER but studies with only healthy non-clinical participants are also important. If I had been including within studies, there would have been too many studies to investigate for this review. I could have had limited the span of years, but I had already finished the first screening process when I decided to exclude within-studies.

5.7 Conclusions

The first aim of this review was to investigate what are the neural effects of MM on ER in adults. The results of the systematic review showed that there are overlapping regions between the subcategories of included studies. The involvement of dlPFC and insular cortex was shown during practicing MM, ER, and when looking at negative stimuli and ACC was reported in both MM- and ER-studies. From this, we can conclude that practicing MM strengthens these regulatory brain regions and as a result, the regions have higher responses during the experience of emotional negative stimuli. The underlying question to my first aim was what difference in neural effects of MM on ER in adults there was between different forms of MM. Because there was only one finding of the involvement of each specific region, with the exception of left dlPFC, this question cannot be answered here. The second aim was to investigate to what extent we can generalize the effects of MM on ER in adults to adolescents. This was discussed with the help of neural and psychological studies. Even if the results from these studies imply that MM strengthens ER in adolescents, they were too diverse to give any answers. To find better answers on the age differences in the effects of MM on ER, researchers need to conduct randomized and controlled neural studies in both age groups based on clear conceptual definitions. The motivational drive for this review was the discussion about what forms of MM are most effective for increasing adolescent's ability to regulate their emotions. Hopefully this review can inspire other researchers to direct their focus more on ER for MM-studies in adolescents and to compare the neural effects of MM and ER to make the relationship between them clearer.

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