Degree project

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Gender Differences in the Neural Basis of Emotion Regulation: A Systematic Review

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Student: Angelina Fridlund

Supervisor: Pilleriin Sikka

Examiner: Joel Parthemore

Abstract

Gender differences in emotion regulation (ER) are well documented, but studies have often relied on behavioral and self-report data. Less is known about gender differences in the neural basis of ER. This systematic review aims to fill this gap and investigate gender differences in the neural basis of ER. The systematic search process ended in eight articles, using either structural or functional neuroimaging methods while investigating the neural correlates of ER using either an ER task to manipulate ER or assessed trait ER with questionnaires. The studies either used reappraisal or expressive suppression as ER strategies. The results were partly inconsistent, but most studies demonstrate the involvement of areas within the prefrontal cortex in ER. Males activated areas involved in cognitive control while females activated emotion-focused areas involved in emotional processing. There is disagreements among researchers whether more activity in the prefrontal cortex represent more effort during ER (and how it does so), as well as whether less activity represent less effort or more efficient regulation. These insights may help us understand each other better. Future research is needed to address if activation within the prefrontal cortex reflects more or less efficiency when regulating emotions.

Keywords: emotion regulation, neural basis, gender differences, neuroimaging.

Gender Differences in the Neural Basis of Emotion Regulation

Emotions guide our behavior and are helpful in situations that require decision-making (e.g., when fear makes you decide to run) and social interaction (e.g., feelings of joy can promote new friendships). However, they can also be harmful, especially when they are of the wrong duration, type, or intensity (Gross, 2014, 2015). This is why the ability to regulate one's emotions is so important. Think of a time when you were so angry that you felt the blood rushing through your body. Suddenly, your friend arrived, and instead of expressing your anger, you smiled. In this case, you had to downregulate anger. Individuals can also downregulate positive emotions, such as trying not to show joy in front of others when winning the lottery (Gross, 2008). People also upregulate positive and negative emotions, such as boosting their positive emotions when in love and negative emotions when preparing to confront a friend who has treated them wrongly (Gross, 2015).

It was not until the 1990s that emotion regulation (ER) became its own branch of research, and since then, interest in the topic has grown exponentially (Gross, 1998, 2014; McRae & Gross, 2020). Previous studies have demonstrated that ER is essential for our health and well-being (Gross & John, 2003; Jazaieri et al., 2013). Research has shown that males and females differ in the strategies used to regulate emotions, which may explain the different consequences of maladaptive ER in the two genders, such as an increased frequency of affective disorders in females and males being more reactive to negative personal stimuli such as anger (McRae et al., 2008; Whittle et al., 2011). While our understanding of the neural basis of ER has significantly grown during the past decades, we know little about the neural basis of gender differences in ER.

What is an Emotion?

Proposing a commonly agreed scientific definition of emotion has been challenging. Most researchers agree that emotions are a multifaceted phenomenon, consisting of an autonomic reaction (e.g., physiological response), experience (e.g., subjective feeling), and an action tendency (e.g., behavioral expression; Sander et al., 2018).

Emotions often involve whole-body responses to events that an individual appraises to be positive or negative (Gross, 2014). Emotions are brief responses, lasting from seconds to minutes, whereas mood is more diffuse (i.e., not associated with specific stimuli) and lasts longer (Gross, 1998, 2014, 2015).

According to the modal model of emotion (Barrett et al., 2007; Gross, 1998, 2014, 2015), emotions develop according to a particular sequence in place: emotion generation starts with a situation, which can be either something in an external environment (e.g., a dog

is chasing you) or internal representations like thoughts (e.g., this dog may bite me). The person then pays attention to the situation (notices a dog running towards him), appraises the situation (e.g., evaluates it as dangerous), and as a result, the heart starts pounding (autonomic reaction), the person feels scared (subjective experience), and the person decides to run away from the dog (action tendency).

Emotion Regulation

ER refers to "the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions" (Gross, 1998, p. 275). Affect regulation is used as an umbrella term, including coping, mood regulation, and ER (Gross, 2015). The ER cycle is best explained by the process model of emotion regulation, built upon the modal model of emotion (Gross, 1998, 2015).

According to this model, there are five families of ER strategies. These include (1) **situation selection**, which involves a strategy of *avoidance* where a person avoids certain situations to avoid specific emotions: e.g., the person decided not to watch a movie because it induces feelings of sadness; (2) **situation modification**, which refers to the strategy of *direct request* (McRae & Gross, 2020, p. 3) where the person acts to influence an ongoing situation: e.g., throw away the bill that causes frustration instead of paying it; (3) **attentional deployment**, which involves the strategy of *distraction* which means taking the attention away from an emotional situation towards a neutral feature: e.g., focusing on the wall instead of looking the person in the eyes; (4) **cognitive change**, which includes the strategy of *cognitive reappraisal*: the process by which a person re-evaluates the meaning of a situation to cope with it: e.g., when you feel that someone does not like you and then instead think this is just your own thoughts and not the truth; another relevant strategy is *distancing,* which involves altering one´s emotional relationship to, or physiological distance from, the stimulus that evokes an emotion: e.g., when you are viewing an emotional situation from a third-person perspective; and (5) **response modulation**, which involves suppression of one's emotional state. For example, e*xpressive suppression* is when a person inhibits the expression of emotion: e.g., keeping the face neutral instead of showing anger. *Physiological suppression* is when a person tries to suppress the physiological response using actions or ingesting substances, e.g., breathing slowly to decrease one's physiological arousal. Finally, *experiential suppression* is the act of suppressing the subjective experience of an emotion: e.g., trying to feel less fear when giving a presentation to an audience (Gross, 1998, 2014, 2015; McRae & Gross, 2020; Ochsner et al., 2012).

Some ER strategies are considered generally adaptive, while others are considered less adaptive. Reappraisal is a generally adaptive form of ER because it can decrease negative

emotion and increase positive emotion. Reappraisal comes with benefits such as improved wellbeing and social interaction (Gross & John, 2003). Expressive suppression is a less adaptive form of ER since it decreases positive but not negative emotions. Contrary to reappraisal, expressive suppression may impair social interaction, increase sympathetic arousal, and is not correlated with increased wellbeing (Gross, 2015; Gross & Levenson, 1997). The most appropriate strategy is challenging to determine because it depends on the person, situation, and desired goals (Gross, 2015).

The goal of ER can either be the desired end goal itself ("I will try not to feel so sad"), or the goal can have other valued ends like regulating one's emotions to achieve another outcome (e.g., when someone tries to impress with an excellent attitude to get the desired job; Gross, 2015). ER can be both conscious and unconscious. Conscious ER, also referred to as *explicit regulation*, refers to when a person is aware of the regulation, such as inhibiting one's laughter when laughter is inappropriate. *Implicit regulation* refers to an automatic response driven by the emotional stimulus itself, such as not showing feelings for fear of rejection (Etkin et al., 2015; Gross, 2015).

To study ER, researchers often try to manipulate ER: e.g., by asking the participants to use a particular ER strategy during a task. This manipulation enables studying ER ability at a particular moment in time. To study trait ER, or more stable individual differences in ER, researchers use questionnaires assessing the habitual use of ER strategies (McRae & Gross., 2020).

The Neural Basis of Emotion Regulation

Studies consistently show the involvement of specific brain regions in ER, such as the lateral prefrontal cortex (involved in cognitive control and working memory) and inferior parietal cortex (involved in cognitive control and spatial attention), ventral anterior cingulate cortex (involved in attention and conflict processing), and ventromedial prefrontal cortex (involved in affective valuations and cognitive control; Etkin et al., 2015; Frank et al., 2014; McRae & Gross, 2020; Ochsner et al., 2012). The involvement of these brain regions differs depending on the chosen ER strategy.

Cognitive change, specifically reappraisal, is by far the most studied explicit ER strategy (Etkin et al., 2015). With reappraisal, researchers have consistently found activation in areas of the prefrontal cortices: namely, the dorsolateral prefrontal cortex (dlPFC; involved in attention and working memory), ventrolateral PFC (involved in inhibition of behavioral response and language), dorsomedial PFC (involved in reflecting on one's affective state), and dorsal anterior cingulate cortex (involved in cognitive control processes; Gross, 2015;

Mostofsky & Simmonds, 2008; Ochsner & Gross, 2008). The frontal areas then up- or downregulate activity in emotion generation systems, such as the amygdala (involved in the detection of emotional stimuli and the processing of arousal), insula (involved in emotional awareness and experience), and ventral striatum (involved in identifying cues that lead to rewarding or reinforcing outcomes; Gross, 2015; Ochsner & Gross, 2008; Ochsner et al., 2012). Several meta-analyses have found consistent activation in the ventrolateral PFC during reappraisal (Kohn et al., 2014; Morawetz et al., 2017), while other meta-analyses found no such activation (Frank et al., 2014; Messina et al., 2015). One meta-analysis conducted by Messina et al. (2015) found consistent activity in the dlPFC, posterior medial PFC, and anterior cingulate cortex during reappraisal with decreased activity in the amygdala and parahippocampal gyrus. Similarly, Frank et al. (2014) found decreased activity in the amygdala and the parahippocampal gyrus during reappraisal.

The neural basis of expressive suppression has been investigated less (Etkin et al., 2015). Like reappraisal, expressive suppression activates the dlPFC, ventrolateral PFC, and dorsal anterior cingulate cortex (Etkin et al., 2015; Goldin et al., 2008). Activation in the right anterior temporoparietal junction (involved in representations of beliefs) has been observed (Morawetz et al., 2017; Ochsner et al., 2012). There are significant differences in frontal activation when comparing reappraisal with expressive suppression. Reappraisal activates frontal areas in the early stages of ER and decreases activity in the amygdala and insula over time, while expressive suppression activates the frontal areas in a later stage in ER processing and increases the amygdala and insula activity over time (Goldin et al., 2008; Ochsner & Gross, 2008).

The neural basis of other ER strategies has been studied even less. Distraction activates the lateral PFC and dorsal anterior cingulate cortex, while activation in the medial PFC and the insula decreases. As with reappraisal, distraction decreases activation in the amygdala (McRae et al., 2010). Distancing is associated with activation in the visual, temporal, and prefrontal regions such as the primary and associate visual cortices, ventrolateral PFC, basal ganglia, and medial PFC (Moodie et al., 2020). Beauregard et al. (2001) found that the anterior cingulate cortex was active during distancing, and just like in reappraisal, activity in the amygdala decreased during distancing. Not much is known about the neural basis of other strategies.

In conclusion, several brain regions are involved independent of ER strategy: activity in the ventrolateral PFC, dlPFC, dorsal anterior cingulate cortex, and medial PFC is increased during regulation, whereas activation in the amygdala and insula are modulated by the former regions (decreased when the goal is to downregulate emotions and increased when

the goal is to upregulate emotions). In contrast, the right anterior temporoparietal junction seems to be involved during expressive suppression, while the visual areas are activated during distancing.

Gender Differences in Emotion Regulation

Research in ER has mainly focused on behavioral experiments and self-reports. Most studies regarding gender differences in ER have focused on psychopathology (McRae et al., 2008), in which emotion dysregulation plays a central role (Nolen-Hoeksema, 2012). Compared to males, females are suggested to develop more emotional disorders (such as anxiety and depression), and this can be linked with disturbances in ER (Gardener et al., 2013; Nolen-Hoeksema, 2012). Psychopathology and ER difficulties have been linked to the inability to use adaptive forms of ER strategies to downregulate negative emotions, such as reappraisal (Nolen-Hoeksema, 2012). Females' tendency to engage in more maladaptive strategies, such as rumination when distressed, and the lack of adaptive strategies may explain the impairments in ER and the related disorders (Nolen-Hoeksema, 2012). Males often use avoidance or suppression, such as substance use, when regulating stressful events and are more likely than females to develop alcohol-disorders (Nolen-Hoeksema, 2012).

In non-clinical samples, Mak et al. (2009) showed that females report more negative emotions than males, and females report feeling more negative emotions after downregulating negative emotions. The authors found no differences regulating positive emotions across genders. Nolen-Hoeksema (2012) argues that gender differences in self-reports can be explained by gender differences in self-perception of one's emotions and perception of stressors in the environment: e.g., females often appraise situations in a more stressful manner than males, and this can affect the ratings in these self-reports.

Previous research has found that females and males seem to differ in their use of ER strategies. Nolen-Hoeksema and Aldao (2011) reported that females use more strategies when regulating emotions, and they use them more often. One possible reason may be that females have more distressing emotions to regulate, and they may be more aware of and understand their emotions better (Nolen-Hoeksema, 2012). This may explain why females engage in more explicit ER strategies compared to males (Nolen-Hoeksema, 2012). However, Garnefski et al. (2004) found that females used maladaptive strategies such as rumination and catastrophizing more often than males. This was supported by Zlomke and Hahn (2010), who found significant gender differences in rumination, with females reporting using it more often. They found no gender differences in the use of reappraisal.

When it comes to males and ER, Gross and John (2003) found that males use expressive suppression more frequently than females, while reappraisal was not used differently based on gender. Kwon et al. (2013) investigated both cultural and gender differences in ER and found that males more often engage in expressive suppression while women ruminate regardless of culture. Nolen-Hoeksema and Aldao (2011) found no gender differences in expressive suppression when measuring with self-reports.

To summarize, while most research regarding gender differences in ER focuses on psychopathology, some non-clinical samples have been studied. Females are suggested to experience more negative emotions and use more maladaptive strategies, while males are more likely to engage in expressive suppression.

Aim of the Thesis

We have quite a good understanding of the neural basis of ER. Based on behavioral and self-report studies, we have relatively good knowledge about gender differences in ER. Less is known about gender differences in the neural basis of ER.

This thesis aims to fill this gap by conducting a systematic review of studies that have used functional or structural neuroimaging methods to investigate gender differences in the neural basis of ER in healthy subjects. The research question is whether there are gender differences in the neural basis of ER, as suggested by previous behavioral and self-report studies and if the underlying neural correlates can explain these findings.

Methods

Literature Search

A literature search was conducted in the databases Web of Science, EBSCO Medline, and Scopus. For each database, the search string was as follows:

("gender differences" OR "sex differences") AND ("affect regulation" OR "emotion regulation") AND (("functional magnetic resonance imaging*" OR "fMRI") OR ("PET" OR "positron emission tomography") OR (“magnetic resonance imaging” OR MRI) OR ("diffusion tensor imaging" OR DTI OR "neur*").

No filters were used. The literature search resulted in 568 articles, which were imported into Rayyan (Ouzzani et al., 2016) to remove duplicates (N =131; see Figure 1). The remaining 437 articles were screened based on title and abstract. The remaining full-text articles (N =37) were critically evaluated according to the inclusion and exclusion criteria. Seven articles were excluded for using wrong methods like electroencephalogram. Nine were

excluded because there was no ER task/condition, and nine were excluded for not looking for gender differences. Three studies were excluded for including some type of emotional disorder, and three were excluded for being a book or review. This left eight articles for systematic review.

Inclusion and Exclusion Criteria

A study was included if it (1) was published in a peer-reviewed journal, (2) investigated the neural correlates of ER using a task to manipulate ER or questionnaires that measured trait ER, (3) employed functional or structural neuroimaging methods, (4) investigated gender differences in ER, (5) was written in English, (6) included only healthy participants (i.e., non-clinical populations) with age above 18.

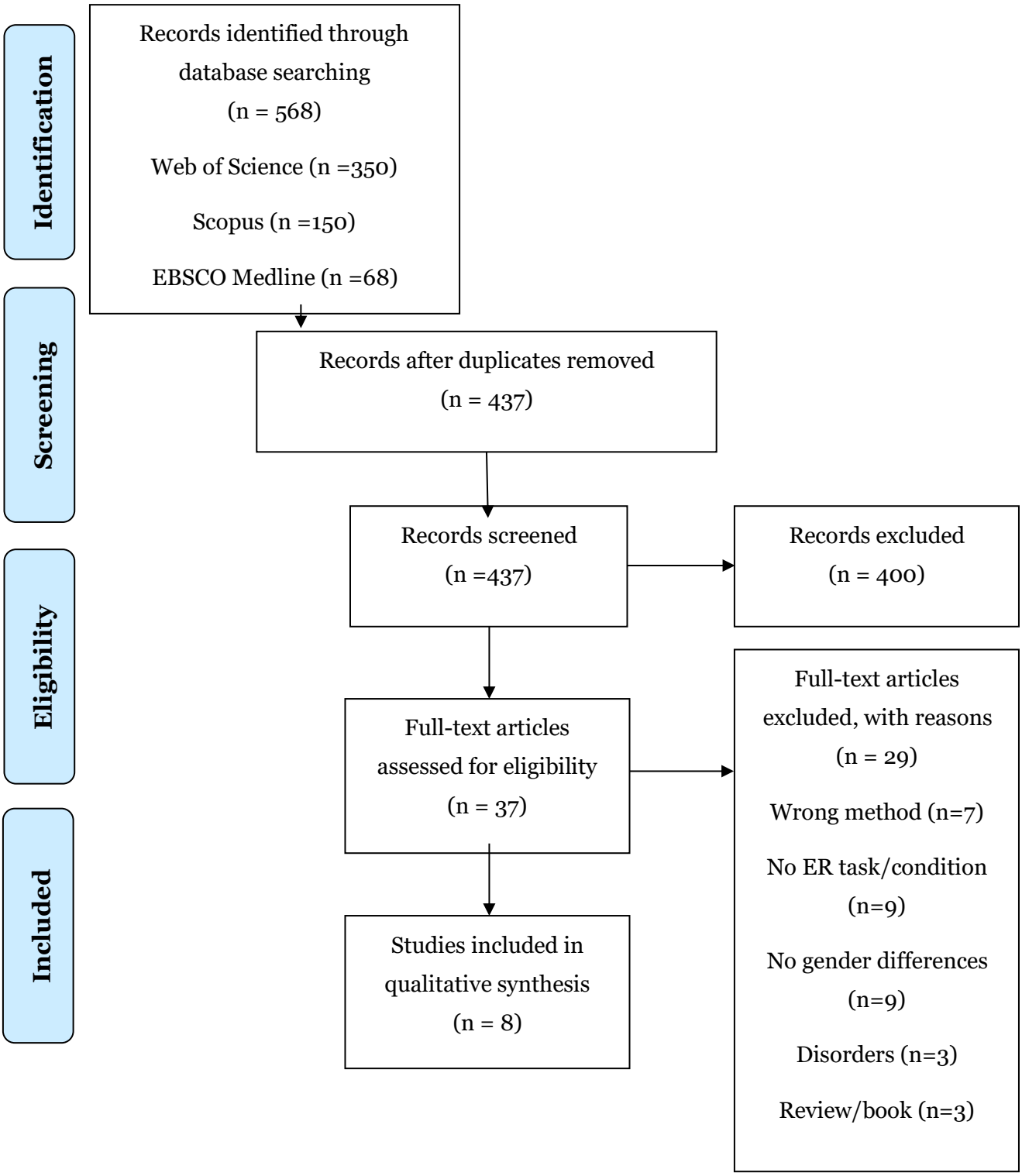
A study was excluded if it (1) investigated implicit (automatic) ER, (2) or investigated children or adolescents.

Data Extraction

The primary outcome measures were functional and structural brain differences between genders in relation to ER. The following data was extracted: article, sample characteristics (size, sex, mean age), neuroimaging method, ER task and stimuli, measurement tool (questionnaires), ER strategy, neuroimaging analysis method (region of interest or whole-brain analysis), and primary conclusion of authors.

Figure 1

PRISMA 2009 Flow Diagram: Literature Search Process



Note: The literature search process is illustrated in a PRISMA 2009 Flow Diagram. Adapted from Moher et al. (2009).

Results

Study Characteristics

Table 1 displays the study characteristics. Altogether, the eight studies had a total of 1003 participants, including 538 females and 465 males. All studies included young adults with mean ages ranging from 19.9 to 25.2. Three studies were conducted in the United States, one in Germany, and four in China.

Regarding neuroimaging methods employed, four studies used functional magnetic resonance imaging (fMRI) for measuring changes in blood oxygenation and flow in relation to neural activity (Domes et al., 2010; Kogler et al., 2015; Mak et al., 2009; McRae et al., 2008). One study used structural magnetic resonance imaging (MRI; Kong et al., 2014), and one study employed both MRI, fMRI and functional connectivity analysis (Wang et al., 2017). One study used fMRI and functional connectivity analysis (Stoica et al., 2021), while one study used fMRI and resting-state functional connectivity (Wu et al., 2016).

Five studies (Domes et al., 2010; Kogler et al., 2015; Mak et al., 2009; McRae et al., 2008; Stoica et al., 2021) used ER tasks: i.e., they manipulated the use of ER and investigated participants' ER ability. All but one study (Kogler et al., 2015) used picture stimuli from the International Affective Picture System (Lang et al., 2008) for the ER task. The regulation strategy was either reappraisal or expressive suppression. Kogler et al. (2015) focused on regulation during a stress condition. The ER task was built into the stress task with one block of non-regulation and one block of regulation (suppression/reappraisal or both). After the regulation task, the participants had to rate which strategy they used using the Emotion Regulation Questionnaire *(*Abler & Kessler, 2009).

Three studies used questionnaires to measure trait ER (Kong et al., 2014; Wang et al., 2017; Wu et al., 2016). Kong et al. (2014) investigated gender differences in the neural basis of ER using the Regulation of Emotion Scale (Wong & Law, 2002), which measures participants' ability to regulate their emotions and how quickly they recover from being distressed. Wang et al. (2017) used the Expressive Suppression Subscale from the Emotion Regulation Questionnaire (Gross & John, 2003; Wang et al., 2007) to measure trait ER of expressive suppression (Wang et al., 2017). Wu et al. (2016) used the Emotional Monitoring and Control subscale from the Emotional Intelligence Scale (Huang et al., 2008), which measures trait ER.

Table 1

Study Characteristics

Article	Sample	Neuroimaging method	ER manipulation	Stimuli	Questionnaire(s)	ER strategy used/tested
Functional neuroimaging studies						
Domes et al. (2010)	(US) N = 33 females (n =17, M = 24.6, SD = 1.6) males (n = 16, M = 25.2, SD = 1.9)	fMRI	reappraisal paradigm (Eippert et al., 2007) *Picture appeared for 3 sec, then instruction to either maintain, increase, or decrease their emotional reaction. The participants had 8 sec to regulate their emotion*	IAPS pictures 72 negative 24 neutral		reappraisal
Kogler et al. (2015)	(DE) N = 43 females (n = 23, M = 24.30, SD = 2.3) males (n = 20, M = 24.85, SD = 3.3)	fMRI	Montreal Imaging Stress Test (Dedovic et al., 2005) (cognitive stress regulation) *During stress-task two blocks of regulation (nonregulation, regulation) in randomized order. Then the participant's had to respond to the ERQ scale while in the scanner.*	non-regulation block: perform task without instructions regulation block: Either modify their negative sensation (suppression) or put less effort in the time-limit and the negative feedback (reappraisal)	Emotion Regulation Questionnaire (Abler & Kessler, 2009) *(e.g., "I did not express my negative emotions" [expressive suppression])*	reappraisal, expressive suppression

McRae et al. (2008)	(US) N = 25 females (n = 13, M = 20.60) males (n = 12, M = 20.36)	fMRI	Event-Related Emotion Regulation Task *First, an instruction word was presented (decrease or look) for four seconds. Then a picture was presented (8 sec) and if the instruction was decrease, then the participant should use reappraisal to decrease the negative emotion. If the instruction was "look" no regulation was done.*	negative and neutral IAPS-pictures a total of 90 trials	reappraisal
Mak et al. (2009)	(CN) N = 24 females (n = 12, M = 24, SD = 1.78) males (n = 12, M = 24, SD = 1.68)	fMRI	Emotion Regulatory Paradigm (Phan et al., 2005) *An arrow was displayed at the screen for three seconds. If the up arrow was shown, they should downregulate negative emotion, while the down arrow represents downregulating positive emotion. If the equal sign appeared, no regulation. Four pictures for each emotion condition (negative, positive or neutral) appeared for 6 sec each (totally 24 sec), the participant's respond according to the cued instruction.*	IAPS-pictures 48 negative, 48 positive and 24 neutral pictures	no specific strategy, only downregulate negative and positive emotions

Stoica et al. (2021)	(US) N= 48 Females (n = 20, M = 22, SD =3,7) Males (n = 28, M = 21,5, SD = 4,1)	fMRI & FC	Emotion Regulation Task *Three parts (baseline, ER and ER rating)* *For the ER part, participants viewed different sets of neutral and negative pictures. First, "SUPPRESS" in red "VIEW" in blue were shown for 500 ms to inform the participants for the upcoming picture. Negative pictures were bordered in red (decrease or detach) and neutral in blue (simply view).*	IAPS-pictures negative (regulation) and neutral (non-regulation)		expressive suppression
Wu et al. (2016)	(CN) N = 258 Females (n = 145, M = 23.12, SD = 2.18) Males (n = 113, M = 22.27, SD = 2.52)	fMRI and resting-state functional connectivity			Emotional Monitoring and Control Subscale (Huang et al., 2008) to measure trait ER. *Participants had to score on a five-point scale from strongly disagree to strongly agree on self-descriptive statements. Low scores indicated low levels of trait ER while higher scores indicated high levels of trait ER.*	
Structural neuroimaging studies						
Kong et al. (2014)	(CN) N = 299 Females (n = 159, M = 21.54, SD = 1.02) Males (n = 133, M = 21.57, SD = 1.00)	MRI			Regulation of Emotion scale (from the WLEIS scale; Wong & Law, 2002) *To measure trait ER ability (the higher score the higher the trait ER ability) and how fast participants can recover from stress, participants were instructed to indicate the extent to which they agree or disagree with each statement in a 7-point Likert-type scale. "I can always calm down quickly when I am very angry".*	

Wang et al. (2017)	(CN) N = 273 Females (n = 149, M = 19.9, SD = 1.25) Males (n = 124, M = 20.10, SD = 1.23)	MRI, fMRI and FC	4-item Expressive Suppression Scale of the Emotion Regulation Questionnaire (Gross & John, 2003; Wang et al., 2007) *Participants were instructed to indicate the extent on a 7-point likely scale. From 1 (strongly disagree) to 7 (strongly agree)* *E.g.: "When I am feeling negative emotions, I make sure not to express them".*	expressive suppression

Note. CN = China. DE = Germany. US = United states. fMRI = functional magnetic resonance imaging. MRI = magnetic resonance imaging. FC = functional connectivity. ER = emotion regulation. IAPS = International Affective Picture System (Lang et al., 2008). WLEIS = Wong and Law Emotional Intelligence Scale.

Functional Correlates of Gender Differences in Emotion Regulation

Table 2 displays the results of the functional studies. The four studies that used fMRI as neuroimaging technique all asked participants to use a particular ER strategy during scanning. Domes et al. (2010) measured gender differences in the use of reappraisal. Analyses with the amygdala as a region of interest showed no gender differences in amygdala activity when upregulating or downregulating negative emotions evoked by pictures. Using whole-brain analysis, the authors found that, when participants were asked to decrease negative emotions (in contrast to maintain negative emotions), males showed increased activation in the right lateral orbital frontal cortex, right posterior dlPFC, right rostral anterior cingulate cortex and left superior temporal lobe, while females did not show increased activation in any area. When participants were asked to increase negative emotions (in contrast to maintaining negative emotions), males showed enhanced activity in the medial paracentral lobule and supplementary motor area, while significantly increased activation was found in the inferior frontal gyrus, middle frontal gyrus, superior temporal sulcus, left fusiform gyrus, left insula, thalamus and hippocampus, and right lingual gyrus. Females did not show increased activity in any areas while increasing negative emotions.

McRae et al. (2008) asked participants to decrease negative emotions evoked by pictures using the reappraisal strategy. Choosing the amygdala as a region of interest, the authors found that males showed greater decreases in the activity of the left amygdala when downregulating negative emotions. The authors also used a whole-brain analysis to investigate activated areas during downregulation of negative emotions (in contrast to viewing of negative pictures). Females showed greater activity in the ventral striatum, anterior cingulate cortex, the superior frontal gyrus, and inferior frontal gyrus. Males showed no greater activity in any area when downregulating negative emotions.

Mak et al. (2009) did not focus on any specific regulation strategy but asked participants to downregulate positive and negative emotions evoked by pictures. Whole-brain analysis demonstrated that females (compared to males) had increased activity in the left medial orbitofrontal gyrus when downregulating negative emotions. In contrast, males showed increased activity in the left lateral orbitofrontal gyrus, left superior frontal gyrus, right anterior cingulate cortex and in the left middle temporal pole and the left middle temporal gyrus. Males displayed weaker activation in the left insula, relative to females. When downregulating positive emotions, both males and females showed stronger activation in the left dorsomedial frontal gyrus and weaker activation in the hippocampus. Males showed stronger activation in the left lateral orbitofrontal gyrus.

Kogler et al. (2015) investigated ER during stressful situations. Participants had to downregulate stressful negative emotions using expressive suppression and reappraisal. Using the amygdala, hippocampus and putamen as regions of interest, findings showed no significant gender differences. Whole-brain analysis showed that both males and females had enhanced activation in the right middle frontal gyrus and right superior temporal gyrus during the regulation, without reaching statistical significance in gender differences.

Gender Differences in Functional Connectivity in Emotion Regulation

Two studies employed functional connectivity and one resting-state functional connectivity to understand the neural networks involved in ER (see Table 2). In the whole-brain analysis, Wang et al. (2017) showed that trait expressive suppression was associated with higher functional connectivity between the default mode network (including the left parahippocampal gyrus, medial PFC, and precuneus) and the left superior frontal gyrus in males, while for females the correlation with expressive suppression was negative. Males showed lower functional connectivity between the left superior frontal gyrus and left middle frontal gyrus, right superior frontal gyrus and right middle frontal gyrus than females. Females had a higher positive functional connectivity between right superior frontal gyrus and left middle frontal gyrus and expressive suppression. The researchers concluded that the functional connectivity between superior frontal gyrus and middle frontal gyrus is negatively correlated with expressive suppression in males, while it is positively correlated in females. The authors used the dlPFC as region of interest and found, without reaching statistical significance, that males (compared to females) had enhanced functional connectivity between the dlPFC and superior temporal gyrus and the middle cingulate cortex and decreased functional connectivity in the postcentral gyrus.

Stoica et al. (2021) investigated gender differences in functional connectivity while participants were performing an ER task to downregulate negative emotions using the expressive suppression strategy. The authors found that females had stronger functional connectivity between the left inferior frontal gyrus pars opercularis and the right posterior parahippocampal gyrus, and between the right inferior frontal gyrus pars opercularis and left parahippocampal gyrus, and finally between the left hippocampus and left parahippocampal gyrus (in contrast to view neutral pictures). Males showed stronger functional connectivity between the angular gyrus and bilateral posterior supramarginal gyrus when downregulating negative emotions.

Wu et al. (2016) investigated the amygdala and its subregions in relation to trait ER (the extent to which participants could control their emotions) in males and females. The authors used bilateral amygdala subregions as regions of interest and found significant

differences in the centromedial nuclei located in the amygdala. For males, a negative resting-state functional connectivity in the medial superior frontal gyrus was positively correlated with ER scores, while for females this was negatively correlated with ER scores. Females showed a strong positive resting-state functional connectivity in the bilateral anterior insula and bilateral superior temporal gyrus and was positively correlated with ER scores in females. Males with higher trait ER show weaker resting-state functional connectivity in the centromedial nuclei, while females show stronger resting-state functional connectivity in the centromedial nuclei for higher trait ER.

Structural Correlates of Gender Differences in Emotion Regulation

Table 3 displays the results of the structural studies. Two studies used MRI. Kong et al. (2014) had two anatomical clusters of interest: one was set at the dlPFC, the second running from the left brainstem to the left hippocampus, left amygdala and the insular cortex. Males showed greater right gray matter volume in the right dlPFC in relation to trait ER ability. Females showed a stronger positive correlation between trait ER ability and gray matter volume in the right hemisphere: specifically, in the cluster from brainstem to left hippocampus, as well as the left amygdala and insular cortex.

Wang et al. (2017) found that expressive suppression was positively associated with thickness in the left superior frontal gyrus in females, although the results were only marginally significant (r = 0.14, p = .079). For males, there was a significant negative correlation between the cortical thickness of the left superior frontal gyrus and expressive suppression (r = -0.25, p = .005).

Table 2

Functional Correlates of Gender Differences in Emotion Regulation

Article	Analysis method	Condition	Activity males>females	Activity females>males	Primary conclusions of the authors
Domes et al. (2010)	ROI (amygdala) & WB	downregulation and upregulation of negative emotion using reappraisal	decrease negative response: R lateral OFC, R posterior dlPFC, R rostral ACC, L superior temporal lobe increase negative response: BL IFG, L MFG, R superior temporal sulcus, L fusiform gyrus, L insula, L thalamus, L hippocampus, R lingual gyrus	---------	Males and females differ in their brain activity. Males had increased activity in brain areas associated with ER when upregulating their emotions compared to females. The increased activity in the PFC in males may indicate a greater use of cognitive strategies when regulating emotions.
Kogler et al. (2015)	ROI (the insula, hippocampus and the putamen) & WB	downregulation of stressful events using reappraisal or expressive suppression	NS	NS	The authors did not find any gender differences in the neural basis of ER in the regulation block
McRae et al. (2008)	ROI (amygdala) & WB	downregulating negative emotions using reappraisal	-------	L amygdala, L ventral stiatum, L IFG, L SFG, R ACC, R posterior cingulate gyrus, BL MFG	Males and females differ in ER. Males showed decreases in amygdala activity during reappraisal, while females had greater ventral striatal activity during reappraisal

Mak et al. (2009)	WB	downregulating negative and positive emotions while not using a specific strategy	negative emotions: L lateral OFG, L SFG, L middle temporal gyrus, L temporal pole gyrus, R anterior cingulate gyrus positive emotion: L lateral OFG	negative emotion: L medial OFG	Males and females differ in ER. While regulating negative emotions, males activated lateral prefrontal regions and females activated the OFG. Both males and females were better at regulating positive emotions than negative.
Wang et al. (2017)	ROI (dlPFC and one cluster from brainstem to left hippocampus, left amygdala and insular cotex), FC	measuring trait ER using expressive suppression subscale of the ERQ (Gross & John, 2003; Wang et al., 2007)	↑positive correlation between parts of the DMN (L parahippocampal gyrus, precuneus) and the L SFG ↓negative correlation Between the L SFG and L MFG, and between the R SFG and R MFG	↑positive correlation between the R SFG and the L MFG	During expressive suppression males showed positively correlated FC in left SFG and areas within the DMN, while females showed a positive correlation for expressive suppression scores between R SFG and the MFG. The SFG seems to make up for the gender differences in expressive suppression regulation.
Stoica et al. (2021)	ROI, FC	downregulating negative emotions using expressive suppression	↑ between the angular gyrus and bilateral posterior supramarginal gyrus	↑between L IFG Oper and R posterior parahippocampal gyrus ↑ between R IFG Oper and L parahippocampal gyrus ↑ between L hippocampus and L parahippocampal gyrus	Males and females differ in the functional connectivity during expressive suppression. Females employed cingulo-opercular network, while males showed connectivity in the posterior parts of ventral attention network while downregulating negative emotions.

Wu et al. (2016)	ROI (amygdala), RSFC	measuring trait ER using the Emotional Monitoring and control subscale (Huang et al., 2008)	↑ higher trait ER; weaker positive RSFC of the: R centromedial nuclei and the L anterior insula R centromedial nuclei and R anterior insula, R STG R centromedial nuclei and L STG ↓ higher trait ER; weaker negative RSFC of the: R centromedial nuclei and R medial SFG	↑higher trait ER; stronger positive RSFC of the: R centromedial nuclei and the L superior temporal gyrus, the L anterior insula and the R anterior insula, R STG ↓higher trait ER: stronger negative RSFC of the: R centromedial nuclei and medial SFG	The neural correlates of trait-level ER showed differences between males and females, specifically in the centromedial nucleus. Females who reported greater trait ER showed enhanced RSFC within the centromedial nucleus while males with higher trait ER showed weaker RSFC in the centromedial nucleus.

Note. WB = whole-brain analysis. ROI = region of interest. FC = functional connectivity. ER = emotion regulation. L = left. R = right. BL = bilateral. RSFC = Resting-state functional connectivity. SFG = superior frontal gyrus. DMN = default mode network. ERQ = Emotion Regulation Questionnaire. OFC = orbital frontal cortex. dlPFC = dorsolateral prefrontal cortex. ACC = anterior cingulate cortex. IFG = inferior frontal gyrus. MFG = middle frontal gyrus. SFG = superior frontal gyrus. OFG = orbital frontal gyrus. STG = superior temporal gyrus. Oper = pars opercularis. NS = non significance. ↓ = negative correlation. ↑ = positive correlation.

Table 3

Structural Correlates of Gender Differences in Emotion Regulation

Article	Analysis method	Condition	Volume ↑ males >females	Volume ↑ females > males	Primary conclusions of the uthors
Kong et al. (2014)	WB	measuring trait ER ability using Regulation of Emotion- scale (Wong & Law, 2002)	R dlPFC	Brainstem L hippocampus L amygdala insular cortex	There are differences in the neuroanatomical basis of ER ability. For males ER ability was associated with R GMV in cognitive process areas while in women they found R GMV in emotion focused areas.
Wang et al. (2017)	ROI (dlPFC and one cluster from left brainstem to the left hippocampus, left amygdala and insular cortex)	measuring trait ER using expressive suppression subscale of the ERQ (Gross & John, 2003; Wang et al., 2007)	negative correlation in L SFG for ER scores	marginally positive correlation in L SFG for ER scores	Females showed marginally significant positive correlation for cortical thickness in the SFG, while males had a significant negative correlation in thickness in the SFG.

Note. ER = emotion regulation. L = left. R = right. GMV = gray matter volume. ERQ = Emotion Regulation Questionnaire. ROI = region of interest. WB = whole brain analysis. SFG = superior frontal gyrus. dlPFC = dorsolateral prefrontal cortex.

Discussion

Summary of Evidence

This systematic review aimed to investigate the currently available research regarding gender differences in the neural basis of ER. Although the findings in these studies were partly inconsistent, there is evidence for gender differences in ER. In the fMRI studies in which reappraisal was investigated during downregulation of negative emotion, Domes et al. (2010) found no gender differences in activity in the amygdala but more significant right prefrontal activity in males compared to females. The opposite was found in McRae et al. (2008), where the results showed decreased activity in the amygdala and less increases in bilateral prefrontal activity in males compared to females. When downregulating negative emotions without a specific regulation strategy, Mak et al. (2009) found that males activated the left prefrontal areas involved in cognitive processing, while females activated medial orbital frontal gyrus, an area related to emotional processing. In contrast, one study did not find any gender differences in ER (Kogler et al., 2015).

Wang et al. (2017) investigated functional connectivity in relation to expressive suppression: males had enhanced functional connectivity between the left superior frontal gyrus and the default mode network, while females had enhanced functional connectivity in the right superior frontal gyrus and left middle frontal gyrus**.** Stoica et al. (2021) found gender differences in expressive suppression, suggesting that males activate the posterior part of the ventral attention network (angular gyrus, and bilateral posterior supramarginal gyrus) while downregulating negative emotions. In comparison, females recruit the cingulo-opercular network (bilateral inferior frontal gyrus oper, left hippocampus and bilateral parahippocampal gyrus) when suppressing negative emotions. Wu et al. (2016) focused on the amygdala and its subregions and found that females with high trait ER had enhanced connectivity in the centromedial nucleus, while this was weaker in males with high trait ER.

Measuring cortical thickness in relation to trait ER ability, males had increased right gray matter volume in areas involved in cognitive processes such as the dlPFC, while females had increased right gray matter volume in areas associated with emotional processes (brainstem, hippocampus, the amygdala, and insular cortex; Kong et al., 2014). Wang et al. (2017) reported differences between gender in the cortical thickness of the superior frontal gyrus in relation to expressive suppression. In males, the thickness of the superior frontal gyrus was negatively correlated with expressive suppression, while in females, there was a marginally positive correlation.

Implications of the Findings

Altogether, the involvement of the PFC seems to play an important role in ER, and the result of this systematic review points out regions within the PFC that seem to underlie gender differences (inferior frontal gyrus, superior frontal gyrus, middle frontal gyrus, orbital frontal cortex, and dlPFC). However, there seem to be disagreements in how the PFC is involved in ER in males versus females. Less activity within the PFC in males may reflect less effort and engagement when regulating emotions (McRae et al., 2008), while more activity in females may indicate more regulation effort (Domes et al., 2010). Alternatively, it may be that more activation in the PFC in males reflects more cognitive processing and more efficient regulation, and the opposite for females (Domes et al., 2010; Mak et al., 2009). These inconsistencies make it difficult to determine whether more or less activity represents efficiency in ER. Some authors speculate that less effort and engagement in males while regulating emotions may be correlated with more implicit (automatic) regulation (McRae et al., 2008), which has been linked to the activation in attention-reoriented areas such as the angular gyrus within the ventral attention network (Stoica et al., 2021).

For both reappraisal and expressive suppression, some studies found that males employ brain areas related to cognitive control, such as the superior frontal gyrus, dlPFC, and middle frontal gyrus, while females engage emotion-related regions such as the amygdala and orbitofrontal cortex (Domes et al., 2010; Kong et al., 2014; Mak et al., 2009; Wang et al., 2017). The role of the PFC in cognitive control is well documented: specifically, the lateral, ventral, and medial PFC (Ochsner & Gross, 2005). During cognitive control, research has found activations in areas such as the dlPFC, which is involved in working memory and attention, and ventrolateral PFC, involved in selecting an appropriate goal, or inhibiting inappropriate goals, and using information from semantic memory to reappraisal the situation (Ochsner & Gross, 2014). These PFC areas were more active in males than females (Domes et al., 2010; Kong et al., 2014; Mak et al., 2009) and may indicate greater use of cognitive control in males. Other studies suggest that females also use areas involved in cognitive control but employ other networks compared to males (McRae et al., 2008; Stoica et al., 2021).

In summary, the functional and structural evidence suggests that males have a higher trait emotion regulation ability than females (Kong et al., 2014), and that males may use less effort downregulating negative emotions (Domes et al., 2010; McRae et al., 2008; Mak et al., 2009). Males tend to use areas related to cognitive control, while females engage emotion-related areas when downregulating negative emotions (Domes et al., 2010; Kong et al., 2014; Mak et al., 2009; Wang et al., 2017). There is evidence that females activate cognitive control areas when downregulating negative emotions, but this may involve different networks than

in males (Stoica et al., 2021). Females may be as efficient as males in downregulating negative emotions, but just use different neural networks to achieve this.

Limitations and Future Directions

The studies included in this systematic review have several limitations. First, using questionnaires to measure trait ER may not represent how much participants actually use a particular strategy in their daily lives; the scores could be affected by participants' current moods and beliefs. For the ER tasks, the lack of self-reports assessing the strategies participants actually used may lead to inconsistent results: participants could have used other strategies than they were instructed to use without being aware of this, and therefore studies could have ended up comparing several strategies (Whittle et al., 2011). In future studies, it is important to assess what strategies participants use and when they use these.

Second, all studies employed young adults, who do not represent the whole population. Previous findings have shown that older females are more likely to engage in suppression than younger females (Nolen-Hoeksema & Aldao, 2011). It would be important for future research to include older adults of both genders.

Third, cultural and personality differences have not been considered. Soto et al. (2011) investigated if expressive suppression affected the psychological functioning of people of different cultures differently. European Americans had more negative psychological functioning, such as depressed mood, while engaging in expressive suppression than Chinese participants. Males have a tendency to be more impulsive and females have a tendency to score higher in neuroticism (Whittle et al., 2011). It is critical in future studies to also control for personality variables as well as to study participants from different cultural contexts.

Fourth, the hormone cycle of females has not been considered in the included studies. Lower frontal and putamen connectivity has been found in females compared to males in the luteal phase (Dan et al., 2019). Sex hormones could affect ER and should be considered when conducting future studies (e.g., by using females who are not in the active luteal phase).

Societal and Ethical Aspects

In all studies, the participants gave informed consent before participating, and all studies were approved by an ethical review board. Regarding societal aspects, if there are significant differences between genders in how they use ER, this may change the way we treat males and females in society. If females activate more emotion-related areas and are more affected by emotional stimuli than males, then the way we conduct interventions and carry out therapy should differ for males and females. For females, therapists may focus on interventions that reduce negative emotions, such as cognitive behavioral therapy and

reappraisal, instead of maladaptive forms of ER that females may otherwise be inclined toward. Males, who are more likely to engage in automatic regulation (McRae et al., 2008), may benefit from learning to use strategies such as reappraisal (Nolen-Hoeksema, 2012). This research is beneficial for society and would provide a better understanding of behavioral differences between genders (e.g., in workplaces and schools), which would help us understand each other better and find better ways to collaborate. Despite the differences between females and males as groups, it is important to consider that differences within genders are more extensive than between genders.

Conclusion

In this thesis, a systematic review on gender differences in the neural basis of ER was conducted. Although the results were inconsistent, evidence shows that males and females differ in their brain activity when regulating emotions. Males activate frontal areas involved in cognitive control, such as the SFG, dlPFC, and middle frontal gyrus. In contrast, females activate emotion-processing areas such as the amygdala, hippocampus, and orbitofrontal gyrus. Future research is needed to understand if activation in these areas reflects more or less efficiency when regulating emotions. This thesis aimed to answer the research question if there are gender differences in the neural basis of ER. The findings of this thesis provide evidence that males and females differ in the activity of different neural networks when regulating emotions. Gender studies in ER are important because they challenge the current beliefs of specific gender roles in society and provide greater insights in similarities and differences between and within genders.

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