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REAPPRAISAL DURING ADOLESCENCE:

A Review of fMRI Studies

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Abstract

Adolescence is a unique period of development. This life phase seems to entail being sensitive to aversive and social cues. However, adolescents' performances have been seen as equivalent to that of adults in nonemotional contexts. For this reason, questions remain regarding adolescents' sensitivity to, and cognitive regulation of, emotional content.
In line with this, the following paper aimed to provide a literature review of the successful use of an emotion regulation (ER) strategy, known as reappraisal, and its normative development during adolescence. Specifically, the main focus of this paper was to review studies investigating age differences of adolescents' reappraisal capacity in association with related functional activity, as measured by functional magnetic resonance imaging (fMRI).
Reappraisal, i.e., to rethink the appraisal of an emotionally eliciting stimulus as to change one's emotional response, is a well-studied psychological phenomenon. Research of reappraisal ability has mainly been studied on adults when viewing aversive images. Therefore, such findings in the field that are of relevance for the more in-depth review are presented. The studies reviewed suggest that reappraisal may account more for age differences in emotional responding than emotional reactivity. Generally, reappraisal ability shows increased success with increasing age. The paper ends with a discussion of results and limitations within the field, such as regarding the various terminology and instructions used for reappraisal tactics.

Keywords: Reappraisal, adolescence, reinterpretation, distancing, fMRI

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Introduction

Adolescence is a unique developmental period (Dahl, 2004). Compared to children, adolescents show remarkable improvements in most domains, such as physical and mental capabilities, and begins to match adult levels of performances. Despite this, mortality rates increase alarmingly during adolescence (Dahl, 2004). Furthermore, as much as 75% of mental disorders present before age 24, and 50% before age 14 (Kessler et al., 2005). Dahl (2004) argues, in part, that emotions have distinctive influence over adolescents' behavior and cognition during this life phase.

The adolescent years are recognized as a life phase that begins by the onset of puberty and ends when societal adult roles are achieved (Sawyer et al., 2018). As society has progressed and health factors have improved, signs of puberty are occurring earlier (Gluckman & Hanson, 2006) and thresholds for adulthood are prolonged (Worthman & Trang, 2018). Compared to previous generations adolescence has become a longer process, which entails a mismatch of maturing biologically before psychosocially (Gluckman & Hanson, 2006; Worthman & Trang, 2018). This prolongation of adolescence may make the transition from depending on parents to more independence more difficult than evolutionary intended (Casey et al., 2010).

Chronologically, no global definitive age range for adolescents exists (Sawyer et al., 2018). At the age of 18 legal privileges usually ensue, and one can be accounted for as an adult. Nevertheless, Sawyer et al. (2018) argue that the age range of 10 to 24 holds for an inclusive definition suitable for today's adolescents, instead of 10 to 18 or 19. This definition includes the teenage years (13-19) and what is termed youth (15-24). The definition reflects maturation society wise, and in terms of neurodevelopment (Sawyer et al., 2018).

A study by Cohen et al. (2016) investigated when individuals would reach maturity in the context of using cognitive control during emotionally arousing states. The participants' ages ranged from 13 to 25, and they performed an emotional go/no go paradigm in which participants are to respond to certain facial expressions, and not respond to other faces. Individuals performed equally well during neutral and positive conditions, however, those who were 21-years and older outperformed younger participants during threatful cues. Cohen et al. (2016) state that while most scientific studies consider those who are 18-years and older to be adults, studies like these can illustrate how even the oldest of adolescents might show maturity differences.

Neurobiological models suggest that adolescents show exaggerated reactivity from limbic regions, such as the amygdala, while not having reached mature recruitment of prefrontal control regions (Casey, 2015). Regions within the prefrontal cortex (PFC) are typically involved in the planning and execution of behavior. These can be divided into four main areas which are anterior to the motor cortex; the dorsolateral- (dlPFC), ventrolateral- (vlPFC), dorsomedial- (dmPFC), and ventromedial- (vmPFC) prefrontal cortex (Gazzaniga et al., 2014). Furthermore, the study of Hare et al. (2008) have been influential for developmental theories, such as the imbalance model (Casey et al., 2008). Like Cohen et al. (2016), an emotional go/no go paradigm for negative stimuli was used (Hare et al., 2008). The paradigm illustrated how adolescent's lack of top-down control over emotional reactivity might put adolescents at risk for anxiety-related disorders.

Using emotional go/no go tasks is a common approach for investigating neural mechanisms of implicit emotion regulation ER. During these tasks, the participants are consciously performing a given task that is seemingly unrelated to ER, but the unconscious by-product performance of regulation is of interest (Braunstein et al., 2017). With this approach, the psychology of how participants perform ER is not in focus when not explicitly instructed to do so, and results risk reflecting emotional reactivity instead of emotion regulation (Silvers & Guassi Moreira, 2019). In contrast to implicit ER, explicit ER then refers to the conscious and effortful attempt at altering one's emotional response (Braunstein et al., 2017). For a review of implicit ER during adolescence, see Ahmed et al. (2015).

Cognitive reappraisal is mainly categorized as an explicit ER strategy (Braunstein et al., 2017), and has gained much attention in the field (McRae & Gross, 2020). The tendency of habitually using reappraisal is usually measured by the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). Reappraisal is suggested to be a putatively adaptive strategy due to its negative association with psychopathology (e.g., Aldao et al., 2010) and positive association with, e.g., psychosocial well-being (Gross & John, 2003). Similarly, adolescents who typically reappraise are more likely to show less depressive and anxiety symptoms (Schäfer et al., 2017) and have better executive functions (Lantrip et al., 2016). Findings of age effects in reported use of reappraisal are mixed, with adults reporting both an increase in the use of reappraisal with increasing age (John & Gross, 2004) and no significant age differences (Allen & Windsor, 2019). A longitudinal study investigating 9 to 15-year-olds found that reported use of reappraisal did not show significant age differences (Gullone et al., 2010). Also, an experience sampling study by Lennarz et al. (2019) found that adolescents aged 12 to 17 years experienced reappraisal to be the successful strategy when down-regulating emotions in everyday life.

While research on differences of reappraisal tendency serves to explore questions about whether or not the strategy is implemented and by whom, what makes for the capacity of performing reappraisal successfully is also of great concern and has received more attention in the field (Silvers & Guassi Moreira, 2019). Due to heightened emotionality, the need for regulation of emotion during adolescence has previously been advocated for by implicit ER (e.g., Hare et al., 2008). However, how adolescents explicitly regulate emotion, and age-differences of this ability, has not been investigated until recent years (Martin & Ochsner, 2016).

On the basis of what has been described thus far, this review investigates potential age differences in terms of the ability to down-regulate negative emotions by reappraisal as measured by functional magnetic resonance imaging (fMRI). Before the more in-depth review of such findings, a background section about appraisal, and what constitutes successful use of reappraisal ability, is presented. Finally, the paper ends with a discussion of results and limitations within the field and the review, before ending with a conclusion.

Emotion Regulation

The control of emotion or emotional aspects of behavior is a complicated question that can be studied by several different approaches while essentially revolving similar questions, therefore, lines need to be drawn between concepts. To begin with, ER may be viewed as part of the umbrella term affect regulation (Gross, 2015). In this way, ER does not refer to coping regulation of stress responses, or mood regulation of longer feeling states, rather the regulation of more fluctuating affective states (Gross, 2015). Also, while it has been shown that both positive and negative emotions can be both up and down-regulated (e.g., Ochsner et al., 2004; Sang & Hamann, 2007), studies of adolescents' capacity to regulate emotion has mainly focused on down-regulation of negative affect (Martin & Ochsner, 2016).

Emotion Generation

Constantly in everyday life, as emotions arise, they may be interpreted and expressed in a number of different ways. According to Gazzaniga et al. (2014), the appraisal theory of emotion generation views a person's subjective evaluation of a stimulus as being principal for emotional processing in determining the emotional response. This group of theories that make for appraisal theory, differs in terms of the criteria used for the assessment of a stimulus (Gazzaniga et al., 2014). According to Smith and Lazarus (1990), we interpret the significance of the stimulus, being environmental or personal, in terms of our well-being. In other words, an emotional state depends on the interaction of the stimulus properties and the appraisal of those as being beneficial or detrimental for oneself (Smith & Lazarus, 1990). The experience of emotion may then be viewed as containing this cognitive mechanism that is appraisal (Barrett et al., 2007).

The amygdala is a subcortical structure important for signaling information of affect-relevant stimuli to other brain regions, making the amygdala known as a hub for emotion generation (Phelps & LeDoux, 2005). However, the amygdala's flow of information and with that emotion generation can take different trajectories depending on the situation. This has been shown by Ochsner et al. (2009) when using fMRI and a condition in which participants view aversive images, or interpret neutral images as aversive. The amygdala may be the first and most active responder to negative stimuli through the bottom-up generation of emotion. Alternatively, emotion may be generated through more top-down representations of how the stimulus may be appraised, coming from PFC-regions (Ochsner et al., 2009).

Age differences in neural activation have been found for emotion generation when individuals are naturally viewing aversive stimuli compared to neutral stimuli (Silvers et al., 2017a). In this study, participant's ages ranged from 6 to 23 years and were viewed social neutral and aversive stimuli, and reported scores of negative affect while being fMRI-scanned.

Scores of negative affect decreased with age, both for neutral and aversive stimuli (Silvers et al., 2017a). Independent of stimuli, activation in the amygdala, temporal cortex, and vmPFC decreased with increasing age. For the amygdala, the decrease in activity was significant until 20 years of age. Also independent of stimuli, activation in the dlPFC and posterior parietal cortex increased with increasing age. Independent of age, the amygdala, anterior insula, dmPFC, and vlPFC were more active when viewing aversive compared to neutral stimuli. In contrast, the vmPFC and dorsal anterior cingulate cortex (dACC) were more active when viewing neutral compared to aversive stimuli.

These results indicated that there was a significant interaction of age and aversive stimuli for PFC regions (Silvers et al., 2017a). At approximately 12,5 years, both the vmPFC and dmPFC were equally active to both neutral and aversive stimuli. However, the direction of activation continued. Activation in vmPFC decreased, and activation in the dmPFC increased, as age increased and in response to aversive stimuli. Based on these results, the authors suggest that as individuals age, there is a shift from relying on ventral medial regions for affective bottom-up processing, to relying on dorsal medial regions for more top-down representations during emotionally evoking processes. How may these associations relate to age differences of effortfully regulating appraisals?

The Process Model of Emotion Regulation

Gross (1998) has referred to emotion regulation as "the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions" (p. 275). This process-oriented framework organizes the ways and time points when emotions may be altered (Gross, 1998). Appraisal is one of several components which make for emotion and might be regulated in the process model (Gross & Barrett, 2011).

The sequential model of emotion generation is at the first level of the process model (McRae & Gross, 2020). It has also been called the modal model of ER (Gross & Thompson, 2007) and depicts the emotion-generative stages. The four stages are situation, attention, appraisal, and response. The situation is the starting point of the process, it begins with the individual experiencing a psychologically relevant situation. This situation may both be evoked externally or internally, and then compels attention in various ways. In the appraisal stage, the person evaluates the situation in consideration of one's current goals, which in turn can activate multiple response systems. The response itself would loop back and change the aspects of the situation, creating a cycle of emotion generation (Gross & Thompson, 2007; McRae & Gross, 2020).

The person-situation transaction makes for the second level of the process model of ER (Gross & Thompson, 2007; McRae & Gross, 2020). This is where five families of ER strategies are organized in relation to the relevant emotion generation stages as targets for regulation. Situation selection and situation modification refer to either seeking out a situation that will most likely have a desired emotional effect, or changing external aspects of a situation, respectively. Attentional deployment can be explained as internal situation selection, except one is selecting where to focus one's attention. For example, when using the strategy of distraction, one chooses to only attend to certain aspects of stimuli, while ignoring other aspects. Cognitive change refers to thinking about what is appraised, i.e., valued, as to alter its significance or one's ability to deal with what it entails. This is what the strategy of cognitive reappraisal intends to do, regulate emotion by changing one's interpretation of the situation. These four ER families are considered antecedent-focused, meaning that they occur before an individual's response systems initiate. The fifth ER family, however, response modulation, is response-focused and intends to regulate the output of responses. For example, by using the strategy of expressive suppression one chooses not to reveal one's true emotional expression (Gross & Thompson, 2007; McRae & Gross, 2020).

The use of situation selection and modification has rarely been studied. However, in a meta-analysis of strategies used by nonclinical samples when down-regulating negative emotion, conclusions were drawn about the effectiveness of the other ER families, and their strategies (Webb et al., 2012). Effectiveness was quantified as the sample-weighted average impact of strategies on emotional outcomes, in terms of behavioral, experiential and physiological measures, not neurally. Cognitive change processes which were types of reappraisal strategies proved to be most effective. The strategy of active distraction, i.e., the explicit goal of attending to positive or neutral aspects of stimuli, also proved to be one of the most effective strategies. Within cognitive change, reappraising by perspective taking, or also known as distancing, was most effective, followed by reinterpreting the context or cause of the stimulus, and lastly was reappraising the response by acceptance. The option of choosing freely between these three strategies proved to be the most effective regulation instruction by far. However, this effect was found based on only six studies.

Successful Reappraisal

fMRI of Reinterpretation and Distancing

As evident by Webb et al. (2012), the extent to which an ER strategy proves successful, or effective, may be influenced by how a strategy is instructed, i.e., by different strategy tactics. The strategy of reappraisal can be performed in several ways as suggested by different taxonomies (McRae et al., 2012b; Powers & LaBar, 2019). The two main reappraisal types or tactics are reinterpretation and distancing (Ochsner et al., 2012). The results of their use are not always distinctly separated in the literature (e.g., Buhle et al., 2014).

Extensive research has investigated the neural underpinnings of ER. Particularly, the down-regulation of negative affect elicited by aversive images through reappraisal (Buhle et al., 2014; Morawetz et al., 2017; Ochsner et al., 2012). How prefrontal areas and other regions interact when exerting reappraisal is not clear. More commonly agreed upon is the understanding that significant decrease of amygdala activity when implementing reappraisal is concordant with reappraisal success.

As described previously (Silvers et al., 2017a), the amygdala is a region central for emotion generation. An exception to the amygdala modulation by reappraisal is the study of Dörfel et al. (2014), which did not find the amygdala to be modulated when using reinterpretation. Hence in neural terms, reinterpretation was not an effective strategy. While detachment, or distancing, did show decreased amygdala activity. This occurred despite self-reports of both reinterpretation and distancing being successful (Dörfel et al., 2014).

Similarly to exerting control in nonemotional contexts, executive functions are suggested to also be recruited for emotional situations (Ochsner & Gross, 2008). In line with this, the vlPFC, dlPFC, dmPFC, and the parietal and lateral temporal cortex, are frequently recruited during reappraisal, while the amygdala becomes attenuated (Buhle et al., 2014). The vlPFC is a region that seems to be recruited independent of ER strategy (Morawetz et al., 2017). However, it is still suggested to assist in the selection of appropriate reappraisals due to its involvement in response inhibition and language processing (Buhle et al., 2014). Through working memory, dlPFC might serve to hold reappraisals in mind, while the dmPFC might be involved in the processing of appraisal information (Buhle et al., 2014).

When separating reinterpretation and distancing in an fMRI study, Ochsner et al. (2004) described distancing as being self-focused reappraisal. When implementing this tactic, one is to alter their personal relevance with the stimuli. Reinterpretation was described as being situation-focused reappraisal. The situational context of what is appraised is to be thought of differently. Amygdala activation decreased during reappraisal, but no tactic differences of this association were reported, while their use was reported as being equally effective in down-regulation of negative affect. However, the tactics differed in that distancing showed more increased activation in medial PFC, while reinterpretation showed increased activation in lateral PFC. It was suggested that this is because reinterpretation entails focusing more on aspects of the external world, such as manipulation of stimuli information. While distancing entails focusing more on aspects of the internal world, such as self-referential judgments (Ochsner et al., 2004). In line with these suggestions, the neural differences of the tactics have been illustrated in relation to mental state attribution (Olsson & Ochsner, 2008). During reinterpretation, ventral lateral PFC areas are recruited for possibly storing helpful information for how meanings of social targets may be reinterpreted. During distancing, medial PFC areas with information of one's internal body states may be recruited in order to manipulate personal connections toward the social target (Olsson & Ochsner, 2008).

Furthermore, Ochsner et al. (2012) suggested that reinterpretation and distancing seem to differ in terms of lateralization, the former is more left-sided and the latter is more right-sided. Reinterpretation may recruit more left-sided prefrontal regions due to dependence on semantic and linguistic processes, and distancing may recruit more right-sided regions due to dependence on attentional and spatial processes.

Besides the extensive literature on the functional activity of reappraisal, research on connectivity between reappraisal-related areas adds knowledge of how the areas may interact (Berboth & Morawetz, 2021). In their meta-analysis which consisted of 15 ER studies in total, a separate analysis was made for only reappraisal studies, but the reappraisal tactics used in the studies were not specified. The amygdala was used as a seed region, and psychophysiological interaction (PPI; Friston et al., 1997) analysis was used. The causality of the interactions could not be inferred due to the constraints of the analysis, however, it was found that successful reappraisal predicts functional connectivity between the amygdala and the vlPFC, dlPFC, and dmPFC. This further supports the notion of prefrontal regions' involvement in the down-regulation of amygdala reactivity during reappraisal.

A Self-Report Study of Adolescents' Reappraisal Success

Before reviewing fMRI studies investigating age-differences of reappraisal ability during adolescence, the work of Silvers et al. (2012) will be presented. Their work consisted of two studies that differed on several accounts. These studies will be referred to when presenting most of the fMRI studies reviewed, such as when describing the used conditions.

While comparing the effects of reinterpretation and distancing, Silvers et al. (2012) investigate whether there are significant age differences in emotional reactivity or reappraisal success. In other words, if age predicts the responsiveness to affective stimuli or the ability to regulate affective responses by reappraisal, respectively, as measured by self-report.

By self-reports of affect, reappraisal success is operationalized as the degree to which negative affect is reduced after implementing reappraisal (Silvers et al., 2012). The reactivity trials with negative stimuli, which are of interest as opposed to neutral trials, are first confirmed as being valenced negative by participants' self-reports of affect. Affect scores from reactivity trials are compared to the affect scores being reported after the effort of decreasing negative affect. Both studies' samples consisted of healthy participants, with an age range of 10 to 23 years.

For study 1, on a trial-by-trial basis, participants viewed either neutral or aversive stimuli and were instructed to either look and react naturally to the stimulus by the Look cue, or implement reappraisal for the Decrease cue, in response to the upcoming image (Silvers et al., 2012). Shortly after each condition, they were asked to select a score of their current negative affect on a scale. The participants trained on implementing reappraisals by saying the reappraisals aloud to confirm that participants understood the instruction before the task. For this study, the reappraisal tactic used was reinterpretation. Silvers et al. (2012) describe that participants were encouraged to tell themselves a story in order to think of a negatively inducing picture as less negative, where an example could be "imagining it's just a scene from a movie" (p. 1236). The stimuli consisted of images, with the International Affective Picture System (IAPS; e.g., Bradley & Lang, 2007) as the main source, and some additional pictures.

Of note, the stimulus material of images used for most studies of ER, including reappraisal, are retrieved from the IAPS (Ochsner et al., 2012). It has been found for adults that neural activations seem to generally overlap when comparing different types of emotionally evoking stimuli, such as images, film, or faces (Morawetz et al., 2017). This suggests that neural activation related to ER is generally independent of the stimulus material used. That said, it has been shown that the stimulus context matters for reappraisal success. For instance, whether or not the stimulus is social in nature, as will be further described from study 2 (Silvers et al., 2012).

Results of study 1 suggest that there were no significant age effects of emotional reactivity, i.e., neither linear nor nonlinear age differences were found (Silvers et al., 2012). However, the use of reinterpretation suggested that there were both significant linear and quadratic effects of age. Specifically, reinterpretation success increased with increasing age (linear effect), but only from age 10 to 16, before no longer showing significant increases in success (quadratic effect).

For study 2, instead of being instructed to either observe pictures as one would normally, or reinterpreting the context of pictures, participants were to be psychologically immersed in, or detached from the content of images (Silvers et al., 2012). Equivalent to the Look cue, participants would imagine themselves being spatially close to what is depicted and free to experience any potential affect, and was referred to as the Close cue. For the regulation trial, in this study known as Far instead of Decrease, participants were to imagine themselves being spatially far away from what is depicted. Also, participants were "to focus more on the facts of the photograph than on its emotional details" (Silvers et al., 2012, p. 1240). For these conditions participants were unaware of the goal of reducing negative affect by implementing a distanced perspective, however, these instructions were used in order to implement the reappraisal tactic of distancing to down-regulate emotion. In order to assess whether age differences of distancing success could be influenced by the sensitivity of social aspects, images were either social or non-social, for both neutral and aversive images. Also, measures of rejection sensitivity were reported. Finally, measures of intellectual ability were reported to investigate if intellectual differences could underlie age-differences of distancing ability.

Results of study 2 showed similar results as study 1 (Silvers et al., 2012). There were no significant linear or quadratic age effects of emotional reactivity. Distancing, however, predicted significant linear and marginally significant quadratic age effects. Since distancing improved linearly from age 10 to 17, and slightly during age 18 as well, before no longer showing significant increases in success. Furthermore, for younger adolescents aged 10 to 13 years, when stimuli depicted aversive social content distancing ability significantly worsened compared to when viewing non-social stimuli, especially for those with higher trait scores of rejection sensitivity. This impact was non-existent for older adolescents, and trait rejection sensitivity was only marginally associated with increased negative affect when not interacting with stimulus content. Finally, although increasing age positively correlated with scores of intellect, results indicated that participants' intellectual ability had no effect on any analysis.

Based on the results of the two studies with regards to age-differences of reinterpretation and distancing success, self-reports suggest that the capacity of using these tactics develop during adolescence. The ability of reinterpretation did not show further significant development after age 16, and about age 18 for distancing (Silvers et al., 2012).

Overall, the research on adult’s successful use of reappraisal suggests that mainly the regions of vlPFC, dlPFC, and dmPFC are recruited in order to down-regulate the more emotion reactive regions of the amygdala. While not finding support for the involvement of vmPFC as a typical reappraisal-related region (Berboth & Morawetz, 2021; Buhle et al., 2014). It has been shown that the reappraisal instructions of using reinterpretation or distancing may differ by its effectiveness (Webb et al., 2012) and their neural underpinnings (Ochsner et al., 2012). Next, a more in-depth review of adolescents' ability to successfully reappraise negative affect while undergoing fMRI is presented.

Review of fMRI Studies Investigating Reappraisal During Adolescence

In the search for studies of relevance, keywords such as “emotion regulation”, “cognitive reappraisal”, “reinterpretation”, “distancing”, “adolescence”, “typical”, “age-differences” and “fMRI” were used on various databases such as PsycINFO, PubMed, Scopus and Google Scholar. As summarized in *Table 1*, through the literature search six original articles of relevance was found. Inclusion criteria for the literature review required studies to use fMRI when investigating age differences of cognitive reappraisal ability for down-regulating emotions in healthy adolescents, when exposed to aversive images.

In order to avoid repetition, some paradigms and findings were the same across studies. All studies used images from the IAPS, which previously mentioned is a common source of aversive images used for this experimental condition. Some studies used additional sources. All studies established that intended elicited affect was experienced by participants, as confirmed by increased negative affect reported for reactivity trials using negative stimuli versus neutral stimuli. Independent of age, all participants reported successful use of reappraisal, and all studies assured that participants used reappraisal as intended through pre-task training. Reappraisal success, by self-report, is operationalized as the degree to which negative affect is reduced during reappraisal trials compared to reactivity trials. Finally, all studies were cross-sectional, no longitudinal effects were investigated.

The participants in all studies were healthy in the sense of not having a current or past psychiatric diagnosis (e.g., Stephanou et al., 2016), i.e., samples were non-clinical. The studies typically used the trial structures of either study 1 (i.e., Look or Decrease) or study 2 (i.e., Close or Far) as previously described by Silvers et al. (2012). When presented, results of age groups are approximate since age was used as a continuous variable for analyses (McRae et al., 2012a). The studies are presented chronologically with one exception. Since the study by Stephanou et al. (2016) aimed to clarify the results of Pitskel et al. (2011) and McRae et al. (2012a), it will be presented before Silvers et al. (2015). A main question of interest was if age-differences of reappraisal ability were found, and in that case, in what manner the ability developed. Next, these articles are presented in more detail, ending with a summary of results.

Table 1
Summary of fMRI studies investigating development of cognitive reappraisal in healthy adolescents viewing aversive stimuli.

Study	Aim	Participants	Paradigm	Results (fMRI activity, connectivity and variability, age-effects during reactivity and reappraisal trials)
Guassi Moreira et al. (2019)	To examine spatial and temporal variability of frontoparietal brain responses during reappraisal, and how this related to age and affective experiences.	70 subjects (F=34). Ages 8-17, no age groups, "younger vs older".	Cross-sectional. CR tactic: Distancing (spatial or objective) Stimuli: Neutral or negative images (all were social). Instructions: Look or Far (distancing, down-regulate).	Reactivity: Uninvestigated. Reappraisal: Uninvestigated. Age-effects: - Reactivity: None, did not investigate. - Reappraisal: Decreased spatial variability in the vlPFC. (Of note) Age-effects of variability: Decreased spatial variability in the SPL. Decreased temporal variability in the vlPFC, dmPFC and MTG.
McRae et al. (2012a)	To examine the development of reappraisal ability in older children, adolescents and young adults, while testing for both linear and non-linear patterns.	38 subjects (F=21). Ages 10-13, n = 12. Ages 14-17, n = 10. Ages 18-23, n = 16.	Cross-sectional. CR tactic: Reinterpretation (3 types; it is not real, things will improve with time, things are not as bad as they appear to be). Stimuli: Neutral or negative images (65% social/faces). Instructions: Look or Decrease (down-regulate).	Reactivity: Increased activation in e.g., amygdala and insula. Reappraisal: Increased activation in prefrontal, parietal and temporal regions. Age-effects (linear): - Reactivity: Increased activation in the fusiform gyrus. Decreased activation in vmPFC. - Reappraisal: Increased activation in the vlPFC. Age-effects (quadratic): - Reactivity: Adolescents showed less activation in e.g., the insula, anterior and posterior cingulate cortex, and STG, compared to children and adults. - Reappraisal: Adolescents showed more activation in e.g., mPFC, posterior cingulate cortex, and temporal poles, compared to children and adults.

Pitskel et al. (2011)	To examine changes in the neural mechanisms of cognitive reappraisal across development.	15 subjects (F=6). Ages 7-17, no age groups, "younger vs older".	Cross-sectional. CR tactic: Pretense (it is not real). Stimuli: Neutral or negative (disgust) images (social, but undisclosed to which extent). Instructions: Look or Decrease (down-regulate).	Reactivity: Increased activation in e.g., the insula, dmPFC and dlPFC. Reappraisal: Increased activation in superior frontal gyrus, angular gyrus, vmPFC. Decreased activation in the insula, dlPFC, dACC, SPL, and amygdala. Age-effects: - Reactivity: Increased activation in inferior parietal lobule. Decreased activation in dACC and anterior insula. - Reappraisal: Decreased activation in e.g., mPFC, vlPFC, and amygdala. No increased activation with age.
Silvers et al. (2017b)	To examine the vlPFC– amygdala pathway hypothesis, and the vlPFC – vmPFC – amygdala connectivity moderation hypothesis.	112 subjects (F=65). Ages 6-23, no age groups, "younger vs older".	Cross-sectional. CR tactic: Distancing (non-specific). Stimuli: Neutral or negative (all were social). Instructions: Close (immersion, reactivity) or Far (distancing, not told explicitly to decrease affective response, only to change perspective). PPI analysis.	Reactivity: Increased activation in the amygdala and anterior insula. Reappraisal: Increased activation in the dlPFC and posterior parietal cortex. Decreased activation in the amygdala. Age-effects: - Reactivity: No age effects. - Reappraisal: Increased activation in the vlPFC. Decreased activation in the amygdala. Age-effect of decreased activation in amygdala was mediated by vlPFC activity. Functional connectivity between amygdala-vmPFC switched from positive to negative with increasing age, and this moderated vlPFC recruitment on amygdala responding.

Silvers et al. (2015)	To examine whether age predicts concurrent and lasting effects of reappraisal across adolescence.	56 subjects (F=31). Ages 10-13, n = 17. Ages 14-17, n = 20. Ages 18-22, n = 19.	Cross-sectional. CR tactic: Distancing (spatial, and focus on non-emotional aspects) Stimuli: Neutral or negative images (half were social). Instructions (2 sessions): Active regulation: Close (immersion, reactivity) or Far (distancing, down-regulate). Re-presentation: Passive viewing. PPI analysis.	Reactivity: Increased activation in the amygdala. Reappraisal: Increased activation in e.g., the dlPFC and posterior parietal cortex. Decreased activity in the amygdala. Age-effects: - Reactivity: No age effects. - Reappraisal: Decreased activation in the amygdala (this correlation was stronger during re-presentation than during active regulation). Increased activation in the rlPFC during re-presentation. Age-effect of decreased activation in amygdala during re-presentation was mediated by rlPFC activity. Increased negative connectivity between the amygdala and rlPFC during active regulation.
Stephanou et al. (2016)	To examine the age-related influences and neural correlates of emotional reactivity and reappraisal in response to aversive social imagery.	78 subjects (F=44). Ages 15-25, no age groups, "younger vs older".	Cross-sectional. CR tactic: Reinterpretation (3 types; it is not real, things will improve with time, things are not as bad as they appear to be). Stimuli: Neutral or negative images (all were social). Instructions: Look or Decrease (down-regulate). PPI analysis.	Reactivity: Increased activation in, e.g., fusiform gyrus, amygdala, insula, dmPFC and dlPFC. Reappraisal: Increased activation in e.g., dACC/dmPFC, dlPFC, insula, angular gyrus, STG. Decreased activity in e.g., amygdala. Age-effects: - Reactivity: No age effects. - Reappraisal: Decreased activation in the amygdala and the fusiform gyrus. Decreased activation in the amygdala was mediated by the fusiform gyrus. Decreased functional connectivity between the fusiform gyrus and the amygdala.

Note: Age-effects are linear if not stated otherwise. General abbreviations: CR = cognitive reappraisal, F = females, fMRI = functional magnetic resonance imaging, n = number, PPI = psychophysiological interactions. Abbreviations for brain areas: dACC = dorsal anterior cingulate cortex, dlPFC = dorsolateral PFC, dmPFC = dorsomedial PFC, mPFC = medial PFC, MTG = middle temporal gyrus, PFC = prefrontal cortex, rlPFC = rostrolateral PFC, SPL = superior parietal lobule, STG = superior temporal gyrus, vlPFC = ventrolateral PFC, vmPFC = ventromedial PFC.

Pitskel et al. (2011)

To the authors' (Pitskel et al., 2011) knowledge, they were the first to conduct a study investigating developmental differences of reappraisal in adolescents compared to children. The participants' ages ranged from 7 to 17, in order to examine developmental trends of reappraisal success. Disgust-inducing types of aversive images were chosen as the reappraisal stimuli and pretense as the reappraisal tactic. Examples of what some of the disgust-inducing pictures illustrated as mentioned by Pitskel et al. (2011) were "moldy food, people vomiting, and roadkill" (p. 326), meaning that pictures could be social but not mentioned to what extent. Pretense, i.e., to pretend, was suggested as being an accessible way for children to engage in cognitive reappraisal. Pretense was instructed as either pretending that what is displayed is right in front of the individual (up-regulate) or by pretending that it is fake (down-regulate). Only that of relevance for down-regulation will be further presented. The trial structure was the same as for Silvers et al.'s (2012) study 1 (i.e., Look or Decrease). After an image had been displayed, and a condition-instruction had been performed, participants were asked on a scale about how disgusted they were, regardless of experienced success in regulation.

Self-report ratings illustrated that children and adolescents successfully down-regulated emotional responses of disgust (Pitskel et al., 2011). Behavioral effects were not significantly modulated by age. During pretense, decreased activation in the insula and amygdala, and increased activation in vmPFC and angular gyrus was observed. Pitskel et al. suggest that the modulation of the insula was due to the insula's relation to disgust. It is also suggested that the increased activation of angular gyrus was because of using pretense as the reappraisal tactic. Increasing age showed that during pretense, PFC regions such as vlPFC, and amygdala activity decreased. Pitskel et al. suggest that less activity reflects less required regulation effort and increased regulation success with age. Furthermore, since the vmPFC and amygdala were inversely correlated, the authors suggest that the vmPFC has a potential regulatory role over limbic structures. The vmPFC might mediate the top-down influence from lateral PFC regions towards the amygdala.

McRae et al. (2012a)

As recognized by McRae et al. (2012a), previous studies had not examined the full developmental trajectory of adolescence, i.e., from childhood to adulthood, in relation to reappraisal success during fMRI. Therefore, the study compared groups of older children, adolescents, and young adults aged 10 to 23 years, in order to investigate potential reappraisal ability changes across development. The trial structure was the same as for Silvers et al.'s

(2012) study 1 (i.e., Look or Decrease). Participants could choose from three types of reinterpretation (see *Table 1*), and most of the negative images were social since 65% of them contained faces (McRae et al., 2012a).

Self-report results confirm that all participants were successful in reappraising, however, there were both significant linear and quadratic age-effects of reappraisal success (McRae et al., 2012a). Furthermore, there were no reported age effects of emotional reactivity. Neurally, there were both significant linear and quadratic age effects for both reactivity and reappraisal, and the non-linear relationships that were found regarded adolescents' social cognition.

During negative reactivity trials, McRae et al. (2012a) observed increased activity in the amygdala and insula. With increasing age, it was found that the fusiform gyrus showed increased activity, and the vmPFC showed decreased activity and no changes in the amygdala. The quadratic effects were that, compared to children (ages 10 to 13) and adults (ages 18 to 23), adolescents (ages 14 to 17) showed less activity in, e.g., the insula, posterior, and anterior cingulate cortices, and some prefrontal regions.

McRae et al. (2012a) reported that there was increased activity in prefrontal, parietal and temporal regions typical for reappraisal, but no significant decrease of activity in the amygdala. The left vlPFC showed increased activation with age. The quadratic effects were that adolescents showed more activity in typical reappraisal regions, e.g., medial PFC and posterior cingulate cortex than children and adults.

Based on these results, in terms of the cognitive regulation of affect, adolescents show linear development with age (McRae et al., 2012a). Moreover, due to a suggested relationship of less mental state attribution-related activity during reactivity trials, while also showing more regulation-related activity in these regions, the authors argue that adolescents show differential recruitment of regions related to mental state attribution, while the use of reappraisal can help balance it.

Stephanou et al. (2016)

Pitskel et al. (2011) and McRae et al. (2012a) showed different results. Stephanou et al. (2016) aimed to investigate if reappraisal success with age may be indicated by either decreased amygdala activity, or increased vlPFC activity, respectively. Due to the finding suggesting that stimuli that are social in nature seem to have an effect on adolescents' reappraisal ability (McRae et al., 2012a), all images were social. Constructed the same way as McRae et al. (2012a), three types of reinterpretation (see *Table 1*) could be chosen from. The trial structure was the same as for Silvers et al.'s (2012) study 1 (i.e., Look or Decrease). The sample consisted of post-pubertal adolescents and young adults, aged 15 to 25 years (Stephanou et al., 2016).

Self-report results indicated that all participants were successful in reappraisal use (Stephanou et al., 2016). Furthermore, there was no reported age-effect of reappraisal success, however, increasing age showed a tendency towards less reported emotional reactivity. Emotional reactivity showed increased activity in several regions, e.g., the fusiform gyrus, amygdala, insula, dmPFC, and dlPFC. There were no significant age-effects of reactivity, neither linear nor nonlinear.

During reappraisal, there was increased activity in the left dACC/dmPFC, left dlPFC, insula, angular gyrus, and superior temporal gyrus (STG; Stephanou et al., 2016). There was decreased activity in the amygdala and in other areas related to the viewing of aversive social stimuli. When investigating age effects, it was found that activity in temporal and parietal cortical regions, fusiform gyrus, and amygdala, decreased with increasing age. Quadratic age effects were tested, but none was observed. No age effects of reappraisal for the PFC were found. However, through further analysis, it was found that the down-regulation of the amygdala with increasing age showed a mediation effect from the fusiform gyrus. Suggesting that reduction of amygdala activity during reappraisal with increasing age was mediated by the fusiform gyrus also showing decreased activity.

By using PPI analysis, functional connectivity between the amygdala, fusiform gyrus, and the dlPFC was also tested for (Stephanou et al., 2016). The dlPFC showed no connectivity with the other regions. However, it was found that the fusiform gyrus and the amygdala showed significantly decreased connectivity during reappraisal, compared to during emotional reactivity, as age increased. In other words, this decoupling between the fusiform gyrus and the amygdala with age was dependent on the reappraisal task.

Based on these results, Stephanou et al. (2016) suggest that the increasing success in down-regulation of the amygdala with increasing age was more associated with the fusiform gyrus than PFC regions. Regions which process information of stimulus features, such as the fusiform gyrus, and regions involved in mental state attribution, such as STG and lateral temporal cortex, were more activated by younger participants. These results support the notion that younger adolescents are more sensitive to aversive social cues.

Silvers et al. (2015)

Silvers et al.'s (2015) study consisted of two sessions. During the first session called active regulation, the trial structure was the same as for Silvers et al.'s (2012) study 2 (i.e., Close or Far). Distancing was instructed as to both imagining to be spatially distanced and to focus on non-emotional aspects of the images. After a short delay (on average 27,5 minutes), during the re-presentation phase, the participants passively view the same set of aversive images as in the active regulation phase. Except for this time, they were not told beforehand that they were to view the same set of images again, they were only instructed to passively view them. By using this approach, the authors argued that differences in the concurrent and sustained age effects of reappraisal could be observed. Since prior regulation would potentially influence the participants' lasting responses to repeatedly viewed aversive stimuli, as opposed to measuring immediate reappraisal twice. No self-report ratings of negative affect were conducted during passive re-presentation in order to not delay the time further between the first and second time of viewing the stimuli. Both functional activity and connectivity were investigated. Half of the stimuli were social, however since it had no significant interactions with either age or strategy in predicting amygdala response, it was not controlled for. The age range of the sample was 10 to 22 years.

In regards to self-report results, all participants effectively made use of reappraisal (Silvers et al., 2015). The linear model of age predicted reappraisal success more so than the quadratic model, therefore, no significant nonlinear effects were observed. There were no age effects of reactivity according to self-reports.

Results revealed increased activation in the amygdala during reactivity trials, and this activity did not differ with age (Silvers et al., 2015). Activity in the amygdala decreased during reappraisal, and increasing age predicted larger decreases. This relationship was strongest during re-presentation compared to active regulation. Activity in the right dlPFC, precuneus, and posterior parietal cortex increased during active regulation, but not during re-presentation and did not differ with age.

For passive re-presentation, there were no observed age-effects of functional connectivity (Silvers et al., 2015). However, during active regulation increasing age was associated with more negative connectivity between the rostrolateral PFC (rlPFC) and the amygdala, and more positive connectivity between the precuneus and the amygdala. Further analysis showed that during re-presentation, as age increased, rlPFC activity increased as well. Age was not related to amygdala decrease after controlling for rlPFC activity, suggesting that rlPFC recruitment mediated the age-effect of sustained decreases in amygdala activation.

Based on these results, Silvers et al. (2015) suggest that when using distancing both immediate and lasting effects are predicted by increasing age. Furthermore, this age effect of reappraisal success by down-regulated amygdala activity is mediated by rlPFC recruitment, and the rlPFC is inversely connected to the amygdala during reappraisal.

Silvers et al. (2017b)

Silvers et al. (2017b) argued that a coherent account of the developmental changes of interactions between lateral PFC and the amygdala during reappraisal was lacking. Therefore, an extensive developmental sample was used. Both in terms of the amount (n=112) and the ages (6 to 23 years) of the participants. The study investigated two hypotheses based on previous studies. The first is the vlPFC–amygdala pathway hypothesis, stating that as age increases, amygdala activation will decrease, and the vlPFC will mediate this relationship. The second is the vlPFC–vmPFC–amygdala connectivity moderation hypothesis, stating that increased activation of vlPFC will decrease amygdala activity, in correlation with negative vmPFC–amygdala functional connectivity. For this hypothesis, support of the first hypothesis needed to be found, and results of functional connectivity between the vmPFC and the amygdala is more negative in correlation with age (Silvers et al., 2017b).

Participants were instructed to use the reappraisal tactic of distancing in order to down-regulate negative affect (Silvers et al., 2017b). The trial structure was the same as for Silvers et al.'s (2012) study 2 (i.e., Close or Far), except that participants were not explicitly told to decrease the affective response, only to change perspective.

Reported negative affect on reactivity trials did not change with age, and the amygdala which showed increased activity did not show age-related differences during reactivity trials (Silvers et al., 2017b). Reappraisal success was highly correlated with increasing age and decreased activation of the amygdala. Through further analysis, it was found that before the age of 9,87 years, self-reported negative affect was not significantly reduced when using reappraisal. Amygdala responses were greater for reappraisal than reactivity during childhood, until this pattern switched during adolescence. For reappraisal, quadratic relationships were tested for but only linear relationships predicted age effects of reappraisal, regarding both neural and self-report findings.

The left vlPFC, right dlPFC, vmPFC, and parietal cortex showed increased activity in correlation with decreases in amygdala activity during reappraisal (Silvers et al., 2017b). Only the vlPFC was a significant mediator of increasing age and decreased amygdala activity. This confirmed the vlPFC–amygdala pathway hypothesis. Primarily when reappraising and not reacting, there was a switch in functional connectivity between the amygdala and the vmPFC, from positive to negative with increasing age. The relationship of increased vlPFC activity and decreased amygdala activity was moderated by the functional connectivity of the amygdala and vmPFC, confirming the vlPFC–vmPFC–amygdala connectivity moderation hypothesis. As Silvers et al. (2017b) describe, “participants with negative vmPFC–amygdala connectivity [older participants] showed a stronger inverse correlation between vlPFC and amygdala recruitment than participants with positive vmPFC–amygdala connectivity [younger participants]” (p. 3508). Furthermore, recruitment of the superior parietal lobule (SPL) was positively correlated with reappraisal success across age.

Based on these results, Silvers et al. (2017b) suggest that reappraisal ability is dependent on functional activity and connectivity changes in PFC regions and the amygdala, and these neural mechanisms develop with increasing age.

Guassi Moreira et al. (2019)

Rather than the magnitude of activation, variability of activation during reappraisal was of interest in the exploratory study by Guassi Moreira et al. (2019). The aim was to investigate potential age differences of both temporal variability, i.e., if activity in a given area varies over time, and spatial variability, i.e., if activity in a given area varies in terms of its distribution. In other words, less temporal variability indicates more consistent, rather than irregular, activation for a given area. Less spatial variability indicates more focal, rather than diffuse, activation, and is assessed by analysing topographic organization of activity patterns. The ages of participants ranged from 8 to 17, and the reappraisal tactic used was distancing. The trial structure was a mix of the ones used by Silvers et al.’s (2012) study 1 and 2, since participants were instructed to observe stimuli naturally (Look) and psychologically distance themselves from the stimuli (Far), spatially or objectively (Guassi Moreira et al., 2019).

Reappraisal success correlated with increasing age (Guassi Moreira et al., 2019). As age increased, temporal variability in the dmPFC, vlPFC, and middle temporal gyrus (MTG) decreased. This suggests that activity in these frontotemporal areas becomes more stable with increasing age. As age increased, spatial variability in the SPL decreased. Furthermore, in correlation with more successful reappraisal, spatial variability in the vlPFC decreased. This indicates that although several reappraisal-related areas showed decreased temporal and spatial variability with age, the only region correlating with reappraisal success was the vlPFC, which was in terms of spatial variability. Based on these results, the authors argue that as variability is reducing in association with age, it makes for enhanced neural specialization. In this case for reappraisal success specifically, the vlPFC showed significant associations.

Summary of Reviewed Studies

Participants from all samples reported successful use of reappraisal for down-regulating negative affect. Age-effects most commonly suggested that it did not predict emotion reactivity, but rather it predicted a linear effect of reappraisal success. Furthermore, most studies suggested that reappraisal success was associated with decreased amygdala activity and increased activity in PFC regions.

Nonetheless, there were cases of inconsistencies from these general results. The only study reviewed which did not report an age effect of decreased amygdala activity associated with reappraisal was that of McRae et al. (2012a). This was the only study that found nonlinear, or adolescent-specific, relationships of reappraisal ability. Two studies did not find age effects of increased reported reappraisal success with age, or increased activity in PFC regions typical for reappraisal. Instead, Pitskel et al. (2011) found that vlPFC activity decreased with age, and Stephanou et al. (2016) found no age-effect of PFC regions. The studies that showed age-effects of emotional reactivity were that of Pitskel et al. (2011), and McRae et al. (2012a). The study of Guassi Moreira et al. (2019) differed from the others in that variability of frontoparietal brain responses during reappraisal and its age effects were of interest, meaning that no results of the amygdala were investigated.

The studies differed in terms of how reappraisal tactics were instructed, how many tactics participants could use, the baseline and goal of conditions, the extent to which stimuli were social in nature, and the samples' age ranges. Such variables will be considered in the discussion while reasoning further on the results of the studies.

Discussion

The aim of this paper was to review studies investigating the typical development of reappraisal ability during adolescence as measured by fMRI. It seems that reappraisal is in general an ability that holds for increased success across development, from childhood/young adolescence into adulthood. One study suggested this ability begins to prove successful at about age 10 (Silvers et al., 2017b). In this section, a discussion about the results from the more in-depth studies reviewed, along with what has been stated in the field in general, is presented.

For adults, it has been found that neural activation related to ER is generally independent of stimulus material used, such as IAPS images or faces (Morawetz et al., 2017).

It seems that social stimuli, including faces, show adolescent-specific patterns when implementing reappraisal (McRae et al., 2012a). Adolescents' sensitivity to faces, or social stimuli, was further supported by the finding of Stephanou et al. (2016). Findings showed that amygdala deactivation was mediated by the fusiform gyrus, a typically involved region for encoding of perceptual features such as faces. Furthermore, these regions showed functional decoupling with age. Since aversive-social stimuli show adolescent-specific associations (McRae et al., 2012a), it would be of interest to investigate age effects of reappraisal ability in relation to social and nonsocial stimuli, while simultaneously comparing reinterpretation and distancing effects. Distancing recruits similar mental state attribution areas (Olsson & Ochsner, 2008), what would then be the difference between neural correlates of viewing social stimuli, compared to using distancing? For both of the mentioned studies (McRae et al., 2012a; Stephanou et al., 2016), different types of reinterpretation instructions were used.

That said, one of those strategies instructed participants to question the reality of viewed stimuli, which is also known as reality challenge (McRae et al., 2012b), or pretense (Pitskel et al., 2011), or even hypothetical distancing (Powers & LaBar, 2019). Therefore, "it is not real" (e.g., McRae et al., 2012a, p. 14), may be considered as types of both reinterpretation and distancing. Alternatively, an approach for how the tactics might be separated is by lateralization of PFC-regions during reappraisal (Ochsner et al., 2012). In fact, adolescent studies were in line with the suggestion by Ochsner and colleagues, which was based on adult studies of reappraisal. McRae et al. (2012a) showed that reinterpretation recruits left vlPFC, and Stephanou et al. (2016) showed that reinterpretation recruits left dlPFC and left dmPFC. Conversely, the studies of Silvers et al. (2017b, 2015) showed recruitment of right dlPFC during distancing. However, such a differentiation is not possible with Pitskel et al.'s (2011) study since pretense did not seem to recruit these regions. Nonetheless, lateralization of related activity supports the notion that differences between reinterpretation and distancing may be manifested neurally. Moreover, whether or not the construct of questioning reality belongs to a certain category of tactics, its utilization value for real-world application may also make the reappraisal itself questionable for its value in the literature (Powers & LaBar, 2019).

Nonetheless, when removing this reappraisal from the selection of reinterpretation tactics in the review, only two variants of reinterpretation remain, "things will improve with time", and "things are not as bad as they appear to be" (e.g., McRae et al., 2012a, p. 14). These reinterpretations could be seen as equivalent to changing future consequences, and changing current circumstances, respectively (McRae et al., 2012b). It would be of interest to investigate age effects of reappraisal ability when implementing these reappraisals separately. Since reinterpretation alone has been shown to be less effective than distancing (Dörfel et al., 2014), while the combination of reappraisal tactics has been most effective (Webb et al., 2012).

The implementation of distancing also seems to imply the option of adding other forms of cognitive regulation at participants' disposal. For instance, the strategy referred to by Webb et al. (2012) as active distraction, which can imply attending to either positive or neutral aspects of stimuli, was used in addition to objective distancing by Silvers et al. (2012, 2015).

The studies differed in how conditions were utilized. The paradigms in the studies of Silvers et al. (2017b, 2015) could be argued as not accurately representing explicit ER since participants were not aware of the regulation goal (Braunstein et al., 2017). For instance, Silvers et al. (2015) investigated lasting effects of reappraisal by having participants view previously reappraised images again while not explicitly told to reappraise. Similarly, in the studies of Silvers et al. (2017b; 2012), participants were told that they were to either immerse themselves in, or distance themselves from stimuli. However, they were not informed about intended purposes of down-regulating affect with the different perspectives. Even though inferences of reappraisal may be drawn from studies with such paradigms, it should be of concern to clarify differences of psychological mechanisms when comparing explicit ER findings (Braunstein et al., 2017).

Furthermore, is the condition intended as being the baseline of emotional reactivity reliable, or could it be categorized as up-regulation versus down-regulation? As mentioned when presenting the study of Pitskel et al. (2011), when instructed to up-regulate affect, participants were to pretend that what is displayed is right in front of the individual. Which is similarly described as spatial immersion, and is the goal of using the Close cue (Silvers et al., 2015). Silvers et al. (2017b) argue that differences of engagement with stimuli may confound reappraisal ability findings when children compared to adults are instructed to passively appraise stimuli. Interestingly, Guassi Moreira et al. (2019) used another variant of having participants passively viewing (Look cue), and regulating emotion by distancing (Far cue), but did not disclose motivation for it.

While general inferences can be drawn about developmental differences in reappraisal success, when combining the variables such as those discussed above, which potentially affects research and findings of reappraisal ability, it undermines its value. A limitation of the field would be the differing approaches of investigation. More work such as that of Powers and LaBar (2019) is needed in order to systematize the strategies and the instructions of them by comprehensive, and updated taxonomies. As stated by Gazzaniga et al. (2014), "Emotion regulation research is in its adolescence." (p. 459).

This review itself is not without its limitations. The scientific field of ER includes several different pursuits of research methodology. Only findings of functional activity from fMRI studies were within the scope of this review, e.g., studies of brain structure were disregarded. However, structural changes related to reappraisal ability may be of interest, especially in relation to adolescents who undergo major structural development in the brain. For instance, the study of Guassi Moreira et al. (2019) found that gray matter structure was related to temporal variability in vlPFC. That said, Silvers et al. (2017b) found that amygdala and vlPFC activation were unrelated to brain structure.

Conclusion

This literature review aimed to present fMRI findings of relevance for age differences of cognitive reappraisal ability during adolescence. A field which is relatively new in comparison to adolescent implicit regulation of emotion and adult studies of what makes for successful reappraisal of emotional responses. The more in-depth reviewed studies suggest that reappraisal is generally an ability that develops with increasing age during adolescence, while also showing adolescent-specific associations when viewing social-aversive stimuli. Emotional reactivity did not consistently account for emotional responses. Furthermore, this review provides a sorting-out of instructions for the reappraisal tactics reinterpretation, and distancing.

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