Dissociation and emotion regulation strategies: A meta-analytic review

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ABSTRACT

Objective: Clinical and neurobiological models posited that dissociative mechanisms might affect processes involved in emotional generation and regulation. However, there is a lack of a comprehensive theoretical framework that systematically includes dissociation within emotional functioning.

Methods: The current study aims at conducting a meta-analytic review on the relationship between dissociation and emotion regulation in order to empirically estimate to what extent dissociation is related to emotion regulation processes. The meta-analysis was based on r coefficient as effect size measure, using a random-effect approach.

Results: The meta-analysis included 57 independent studies for a total of 11596 individuals. Findings showed an overall moderate relationship between dissociation and emotion regulation ($r_w = .32$; $p < .05$). The association between dissociation and emotion regulation was the same among clinical samples than non-clinical ones. Furthermore, dissociation showed moderate to large relationships with maladaptive domains of emotion regulation, namely disengagement ($r_w = 0.34$; $p < .01$) (i.e., behavioral avoidance, experiential avoidance, thought and emotional suppression) and aversive cognitive perseveration ($r_w = 0.38$; $p < .001$) (i.e., rumination, worry and nonacceptance). The analysis did not find significant relationship between dissociation and adaptive domain of emotional regulation (i.e., problem solving, mindfulness).

Conclusion: Dissociation in the context of emotion regulation might be viewed as a basic neuro-mental mechanism that automatically contribute to the over-modulation of emotional states through avoidance reactions from internal and external reality. Future longitudinal studies are needed to clarify the causal relationships between dissociation and emotion regulation.

1. Introduction

1.1. Dissociation as a complex construct

Despite the historical interest in studying the multifaceted construct of dissociation, is the debate regarding its operationalization is still open and not definitive (Van der Hart and Dorahy, 2009). Departing from psychopathology classification, the ICD-11 (World Health Organization, 2018) describes dissociation as the "*involuntary disruption or discontinuity in the normal integration of one or more of the following: identity, sensations, perceptions, affects, thoughts, memories, control over bodily movements, or behavior*" (World Health Organization, 2018). Similarly, the DSM-5 (American Psychiatric Association, 2013) emphasizes the loss of high-order integrative and regulative capacities: "*disruption of and/or*

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discontinuity in the normal integration of consciousness, memory, identity, emotion, perception, body representation, motor control, and behavior". Following the DSM-5, dissociative symptoms are also experienced as *"unbidden intrusions into awareness and behavior, with accompanying losses of continuity in subjective experience"* (e.g., fragmentation of identity, depersonalization, derealization) — and/or *"inability to access information or to control mental functions that normally are readily amenable to access or control"* (e.g., amnesia).

Referring to dissociation as a constellation of symptoms, they involve two main types of manifestations (van Dijke et al., 2010). Specifically, positive ones include intrusive symptoms, such as reexperiencing traumatic memories, whereas negative ones refer to "*apparent losses — apparent because experiences that tend not to be available to one dissociative part of the personality may actually be available to another part*" (van Dijke et al., 2010, p. 426). Dissociative symptoms are further categorized into *psychoform* (Maldonado and Spiegel, 1998) and *somatoform* (Nijenhuis, 2001, 2004; Nijenhuis et al., 1996). Somatoform dissociation refers to both positive (e.g., pain) and negative (e.g., anesthesia) physical symptoms (e.g., Nijenhuis, 2004).

However, one of the most influential approaches to dissociation conceptualizes this construct as a psychological dimension (Putnam et al., 1993; Ross, 1996). Specifically, dissociative phenomena range from milder forms with no or minimal interference on adaptation (e.g., absorption, daydreaming, or trance-like behaviors; Dalenberg and Paulson, 2009; Eisen and Carlson, 1998), which represent alterations in the field of consciousness and in the level of consciousness (Van der Hart et al., 2004), to pathological pervasive forms such as in trauma-related and dissociative disorders (Coons, 1996; Van der Hart et al., 2004). Going to the extreme of continuum, some authors have conceptualized dissociation a structural pathology of personality (theory of structural dissociation of the personality [TSDP]; Nijenhuis and Den Boer, 2009; Van der Hart, Nijenhuis, and Steele, 2006). The TSDP posits a loss of integration between parts usually mediated by daily life action systems (i.e., activities of daily life and survival of the species) and defensive action systems (i.e., a range of subsystems dedicated to the survival of the individual in the face of threat) as a result of the insurgence of a threat to bodily integrity and/or life (Van der Hart et al., 2004). The two major prototypes of dissociative parts that TSDP distinguishes are referred to as emotional parts and apparently normal parts (Myers, 1940) that, respectively, aim to defend the individual from threats and to fulfil functions in daily life.

An additional proposal to conceptualize dissociation has been proposed by some authors who suggested to focus on two key processes underlying several dissociative phenomena, namely *compartmentalisation* and *detachment* (Allen, 2001; Holmes et al., 2005). Despite there is not conclusive considerations regarding a well-accepted operationalization of these mechanisms, Holmes et al. (2005) attempted to provide a clear description of them based on an extensive review that included evidence from different perspectives (e.g., phenomenological, factor-analytic and experimental studies). On the one hand, compartmentalisation is characterized by a "*deficit in the ability to deliberately control processes or actions that would normally be amenable to such control*" (Holmes et al., 2005; p. 7), which includes an inability to bring normally accessible information into the field of consciousness. Compartmentalised processes continue to operate normally (apart from their inaccessibility to volitional control), and influence ongoing emotion, cognition and action (Brown, 2006). Compartmentalisation processes could underpin different dissociative symptoms such as dissociative amnesia, conversion symptoms, other somatoform dissociation symptoms, and 'body memories' (i.e., re-experiencing traumatic pain in the body) (Nijenhuis and Van der Hart, 1999; Van der Kolk, 2014). On the other hand, detachment is defined by the subjective experience of an altered state of consciousness characterized by "*a sense of separation from certain aspects of everyday experience* (Holmes et al., 2005; p. 5; p. 5)" from the body, emotion experience, sense of self or the external world.

According to Holmes and colleagues' (2005), detachment

mechanisms might be linked to a wide range of dissociative symptoms including, absorption, derealization, depersonalization, together with the absence or alteration of emotional experience (e.g., numbing). However, a clear separation between these dissociative mechanisms and related phenomena is complex and not always recognizable. For instance, dissociative amnesia is mainly viewed as a compartmentalisation phenomenon. Nevertheless, the same dissociative phenomenon could be a consequence of an altered state of consciousness linked to detachment mechanisms, which interfere with the encoding and storage of information (e.g., deficit of encoding and storage of traumatic material). Moreover, compartmentalisation and detachment could be commonly involved in both adaptive (e.g., absorption, hypnotic states) and maladaptive (e.g., depersonalization, identity alterations) dissociative phenomena.

In conclusion, dissociation might be considered a complex construct that includes a wide range of phenomena that could be sustained by alterations of integration processes of several domains of mental functioning within the field of consciousness, which might affect regulatory capacities of human brain and mind (Scalabrini et al., 2017, 2020a; Farina et al., 2019; Schimmenti and Sar, 2019).

1.1.1. The assessment of dissociation

Historically, several valid and reliable instruments have been developed to assess dissociation for clinical and research purposes. With respect to dimensional approaches to dissociative phenomena, there are numerous self-report assessment tools that capture different features of dissociation and related phenomena. For instance, the Tellegen Absorption Scale (Tellegen and Atkinson, 1974) measures the tendency in experiencing states of absorption, which have been operationalized as episodes of "total" attention that fully engage one's representational (i. e., perceptual, enactive, imaginative, and ideational) resources. The Perceptual Alteration Scale (Sanders, 1986) has conceptualized dissociation as a personality trait that covers the tendency in feeling modification of connections among affect, cognition, and perception of voluntary control over behavior, together with alterations in the subjective experience of affect, voluntary control, and perception.

Furthermore, there are some questionnaires — the Questionnaire of Experiences of Dissociation (Riley, 1988), the Dissociative Questionnaire (Vanderlinden et al., 1993) — developed to evaluate the frequency of a wide range of dissociative phenomena, which range from normal (e. g., daydreaming) to pathological (e.g., derealization; identity confusion) forms. Despite the large number of instruments, the most commonly used for the assessment of dissociative experience is the Dissociative Experiences Scale (DES; Bernstein and Putnam, 1986; Carlson and Putnam, 1993). The DES was built on the assumption of a dissociative continuum, which range from mild normative (i.e., absorption, amnesia) to severe pathological (i.e., depersonalization, derealization) dissociation and it assesses the percentage of the time one experiences each dissociative phenomenon.

Referring to maladaptive forms of dissociation, these are measured using assessment tools for psychological reactions to traumatic events, considering both short- (Peritraumatic Dissociative Experiences Questionnaire; Marmar, Weiss, and Metzler, 1997) and long-term (e.g., Trauma Symptom Checklist, Gleaves and Eberenz, 1995; Trauma Symptom Inventory-2; Briere, 2011) periods of evaluation. Further instruments developed to assess the severity of specific maladaptive forms of dissociation are the Cambridge Depersonalization Scale (Sierra and Berrios, 2000) and Somatoform Dissociation Questionnaire-20 (Nijenhuis et al., 1996). Ultimately, there are also two clinical interviews that represent the gold standard for assessing dissociative disorders according to DSM criteria, namely the Structured Clinical Interview for Dissociative Disorders (SCID-D; Steinberg, 1993,1994) and Dissociative Disorders Interview Schedule (DDIS; Ross et al., 1989).

1.2. Emotion regulation processes

Different theoretical perspectives have described emotion regulation considering processes involved in influencing positive and negative emotions consciously or automatically, in terms of intensity, duration, and/or quality (Naragon-Gainey et al., 2017). With respect to this broad conceptualization, Naragon-Gainey et al. (2017) identified three groups of theoretical models of emotion regulation:

  i) the temporal-based models (e.g., Gross, 1998; 2015) yield specific emotion regulation strategies for each stage of emotion generation, namely situation selection (e.g., avoidance of environmental contexts altogether) and situation modification (e.g., changing or avoiding specific features of a situation), attentional deployment (e.g., distraction), cognitive change (e.g., reappraisal), and response modulation (e.g., expressive suppression)
  ii) the strategy-based models (e.g., Aldao and Nolen-Hoeksema, 2012; Aldao et al., 2010) identify "adaptive" (e.g., acceptance, problem solving, mindfulness) and "maladaptive" (e.g., experiential avoidance, rumination, worry) emotion regulation strategies in the light of their negative and positive relationships with psychopathological symptoms, respectively,
  iii) the ability-based models of emotional regulation (e.g., Berking et al., 2008; Gratz and Roemer, 2004) capture dispositional abilities (e.g., ability to engage in goal-directed behavior when experiencing negative emotions, access to emotional regulation strategies perceived as effective) that are involved in different emotion regulation strategies and situations. These models hypothesize that such dispositional abilities are equally involved in both adaptive and maladaptive emotional regulation strategies and situations.

Despite these differential theoretical perspectives to emotion regulation processes, Naragon-Gainey et al. (2017) recognized a common set of emotion regulation strategies shared by these models. Investigating the latent structure of these emotion regulation strategies using a meta-analytic approach, the authors found a three-factor model:

1) the first factor was labeled "disengagement" and, it was indicative of different forms of attentional and behavioral avoidance (i.e., distraction and behavioral avoidance, experiential avoidance and expressive suppression);
2) the second factor was named "aversive cognitive perseveration". This domain captured emotion regulation strategies characterized by an over-engagement with negative cognitions and difficulties in tolerating emotions (i.e., worry, rumination and low acceptance);
3) the last factor was called "adaptive engagement" and, it included problem solving, mindfulness and reappraisal emotion regulation strategies. These emotion regulation strategies reflect exposure-based attitudes towards emotion-eliciting situations and different features of affective responses (e.g., physiological, behavioral, experiential) in order to adaptively modulate them.

Despite disengagement and aversive cognitive perseveration were distinct factors, meta-analytic results showed that they significantly correlated to each other. Therefore, these dimensions might share a common underlying mechanism, which might refer to a function of avoidance of different aspects of emotional reactions as a key process to alter the duration, intensity and/or quality of them (e.g., Behar et al., 2009; Watkins and Moulds, 2005). Moreover, these domains of emotion regulation are typically associated to several forms of maladjustment, especially when they are rigidly use within different contexts and situations (Aldao et al., 2010; Sheppes et al., 2014; Wilson and Gilbert, 2008).

However, this clear distinction between adaptive and maladaptive emotion regulation strategies was called into question, taking into account empirical evidence that showed different cost-benefit trade-off of several emotion regulation strategies with respect to short- and long-term effects on emotional reactions (for reviews see: Sheppes, 2020; Sheppes and Gross, 2011). For instance, the benefit of early attentional disengagement from emotional stimuli (e.g., distraction) is an effective reduction of the intensity of physiological components of emotional reactions using minimal cognitive resource expenditure (Shafir et al., 2015). However, long-term costs of this mechanism refer to a lack of a detailed elaboration of emotional-eliciting situations that do not allow to develop an elaborated cognitive representation of such stimuli (e.g., Sheppes and Meiran, 2008). On the contrary, later reappraisal of emotional stimuli shows less effective short-term consequences on modulation of emotional reactions, especially considering the relevant cognitive resource expenditure (e.g., Schönfelder et al., 2014). Nevertheless, the long-term benefits of engagement meaning change are that the negative effects of specific emotion-eliciting situations can be gradually processed and definitely solved (e.g., Ahn et al., 2015).

Taking together this evidence, adaptive and maladaptive effects of emotion regulation domains should be viewed in the light of the organization of selection processes of emotion regulation strategies. Specifically, adaptive emotion regulation is characterized by a flexible, dynamic, and balanced selection of different emotion regulation strategies over the stages of emotional generation, which simultaneously considers both short-term (e.g., intensity of emotional situations, availability of cognitive resources) and long-term (e.g., personal goals and values) features of each emotional-eliciting context (Sheppes, 2020). On the contrary, maladaptive emotion regulation should be identified by rigid and context-insensitive selection of emotion regulation strategies, together with difficulties in reaching a balanced selection among strategies short- and long-term demands of emotional-eliciting situations and related reactions (Sheppes et al., 2015).

1.3. Dissociation and emotional functioning

According to different theoretical approaches previously discussed, human emotional functioning could be specifically altered by effects of dissociative processes and symptoms. For instance, emotional-eliciting events might be dissociated from memory facilitating the onset of automatic and intense affects that are manifested in a chaotic and incongruous form, such as unmanageable fears, anxiety (Carlson et al., 2009). Dissociative symptoms and mechanisms might also interfere with a coherent encoding of salient events (Petersen and Posner, 2012; Conway and Pleydell-Pearce, 2000) leading to an unintegrated experience where different aspects of the event such as its sensory, affective and cognitive features are separately encoded and disintegrated automatically (Van der Kolk and McFarlane, 1996; Bremner et al., 1998; Foa and Riggs 1995). Stressful affects, especially those associated with emotional pain, are consequently not experienced in consciousness nor integrated within the self, leading to what Bromberg (2003) terms "not-me" self-states. Furthermore, dissociation might facilitate the unexpected and nonvoluntary onset of overwhelming affects due to alterations of integration processes (Carlson et al., 2009; Liotti, 2009; Schore, 2009; Meares, 2012; Scalabrini et al., 2020b). These might lead to the fragmentation of those mental activities (e.g., attention, behavioral strategies) involved in adaptive emotion regulation (Zelazo and Cunningham, 2007). Some models have also conceptualized dissociation similar to the nonvoluntary freezing response observed in animals in situation that cannot be controlled. Specifically, the threatening organism may be engaged in a kind of passive automatic defense mode, accompanied by a shut-down of the arousal system and an increased parasympathetic activity (Gershuny and Thayer 1999; Hagenaars et al., 2014). Together, several clinical and neurobiological models theorized and demonstrated that dissociation might affect human emotional functioning. Nevertheless, there is a lack of a comprehensive theoretical framework that systematically considers dissociation within emotional generation and regulation processes.

Despite this absence, it could be possible to hypothesize how dissociation and affective functioning reciprocally influence each other. Several theories of emotions converge in identifying common aspects involved in generating an affective reaction (Gross, 1998): a) external or internal stimuli; b) attentional resources intentionally or non-voluntary focused on specific cues of the emotional-eliciting situation; c) conscious or unconscious appraisals of situation; d) onset of emotional response tendencies (i.e., physiological, behavioral, experiential); e) emotional expression. According to these stages of emotional generation, dissociation could nonvoluntary affect attention and perception needed to integrate emotional-eliciting stimuli in the field of consciousness (e.g., derealization, depersonalization, compartmentalisation) (Haaland and Landrø, 2009). Dissociation might also affect appraisal processes in two different ways. On one hand, maladaptive effects of dissociation on attentional and perceptual functions do not allow developing a complex and integrated mental representation of emotional-eliciting situation and related personal meanings (Foa and Hearst-Ikeda, 1996). On the other hand, the defensive mode associated to dissociative mechanisms sustains automatic and rigid threat appraisals of a wide range of emotional-eliciting situations (Morgan et al., 2001).

Despite the previous considerations refer to the impact of dissociation on processes temporally preceding the onset emotional reactions, these mental phenomena might also impact different domains of emotional response itself. Indeed, dissociation could shut down physiological arousal, interfere with emotional feelings (e.g., emotional numbing, anesthesia) and facilitate the expression of dissociative-based behaviors linked to distressing emotions (e.g., dissociative convulsions, *stupor*) (e.g., Sack et al., 2012; Holmes et al., 2005). However, it might be possible that intense affective states trigger dissociative reactions. Indeed, it was empirically demonstrated that intensity and duration of extreme aversive emotional arousal were related to the onset of psycho- and somatoform dissociative phenomena, especially among patients with borderline personality disorder (Stiglmayr et al., 2008; Stiglmayr et al., 2001). The intensity of arousal induced by experimental procedures (i.e., hyperventilation provocation test) was also linked to dissociative experiences among civilian trauma survivors with acute stress disorder (Nixon and Bryant, 2006). Dissociative reactions were also linked to carbon dioxide inhalation, which represents a well-validated experimental paradigm for inducing panic (Rassovsky and Kushner, 2003), among patients with post-traumatic stress disorder and panic disorder (Muhtz et al., 2011). Interestingly, it was also demonstrated that dissociative reactions could be induced administering high frequency visual and auditory stimuli among nonclinical subjects (Leonard et al., 1999).

Therefore, dissociation seems to be link to affective functioning in two different, albeit interrelated, ways. On one hand, dissociative phenomena could be viewed as automatic mental phenomena that affect each stage of emotional generation – perception of emotional-eliciting cues, cognitive appraisal of emotional-eliciting situation and emotional responses (i.e., physiological, experiential, behavioral). On the other hand, dissociation might be considered a nonvoluntary reaction to high frequency emotional-eliciting stimuli and high intensity emotional arousal. Nevertheless, the empirical relationship between dissociation and emotion regulation processes remains not systematically organized.

Taking together meta-analytic evidence concerning the latent structure of emotion regulation strategies together with functional links between dissociation and emotional reactions, we might suggest a possible integration of dissociative mechanisms within emotion regulation processes. According to several neurobiological and clinical models (e.g., Lanius et al., 2010; Liotti, 2004; Sierra and Berrios, 1998; Schore, 2009), dissociation could be viewed as automatic and nonvoluntary processes that attempt to modulate emotional reactions affecting each stage of their generation. Specifically, dissociative phenomena might play a key function of a not deliberate avoidance of different aspects of emotional reactions (Foa and Kozak, 1986; Wagner and

Linehan, 1999), which induces a short-term unresponsiveness (Ebner-Priemer et al., 2009; Griffin et al., 1997; Lanius et al., 2002; Sierra et al., 2002) as a modulatory mechanism of affective states. However, it has been well-demonstrated that these forms of emotional avoidance produce a long-term rebound effect on affective functioning, especially increasing the duration and intensity of emotional responses together with heightened distressing quality of emotional experiences (Gross and Levenson, 1993; Gross and John, 2003; Wenzlaff and Wegner, 2000). Furthermore, dissociative reactions might not allow to access to voluntary meaning change strategies (e.g., reappraisal) of emotional-eliciting situations with long-term benefits of emotional functioning.

Referring to Sheppes' (2020) theoretical framework, dissociation could represent a factor involved in reinforcing maladaptive emotion regulation in the light of an unbalanced cost-benefit trad-off, which favor short-rather than long-term effects on modulation of intensity, duration and quality of affective states. Consistently, dissociation could be also view as a constellation of automatic and nonvoluntary mechanisms that interplay with dysfunctional domains of emotion regulation (i.e., disengagement, aversive cognitive perseveration) characterized by rigid and inflexible strategies (e.g., experiential avoidance, suppression nonacceptance, rumination) used to influence the intensity, duration, and quality of emotional reactions. Furthermore, dissociation and the other maladaptive emotion strategies might share the avoidance function of different aspects of emotional reactions as the key processes to alter them. Ultimately, dissociation and dysfunctional emotional strategies might represent risk factors for each other in the light of their ineffectiveness in modulating emotional states in order to adaptively respond to internal and external emotional-eliciting situations (see Fig. 1 for a graphical representation of the relation between dissociation and emotion regulation strategies considering each stage of emotion generation). Despite these considerations, the strength of association between dissociation and different forms of emotion regulation still remains unclear. Furthermore, there are no studies that have comprehensively summarized empirical evidence on such topic. This seems to be crucial in order to propose an evidence-based model of dissociation within emotional regulatory functions.

1.4. The present study

The current study aims at conducting a meta-analytic review on the relationship between dissociation and emotion regulation in order to empirically estimate to what extent dissociation is related to emotion regulation processes. The study expect an overall significant association between dissociation and emotion regulation. This evidence should reflect the hypothesized role of dissociation within each stage of emotion generation. Furthermore, it is assumed a positive relationships with maladaptive emotion regulation strategies and negative associations with adaptive domain of emotion regulation, considering the well-established dysfunctional effects of dissociation on emotional functioning. Considering absolute values of these associations, dissociation should highlight more robust relationships with maladaptive domains of emotion regulation (i.e., disengagement and aversive cognitive perseveration) than adaptive one. The maladaptive relationship between dissociation and emotion regulation is also investigated postulating significant differences between pooled effect sizes of clinical and nonclinical samples in the strength of association between these dimensions. Ultimately, the study also investigate relationships between dissociation and each emotion regulation strategy in order to test whether dissociation could be linked to specific emotion regulation strategies within each domain and stage of emotion generation.

2. Methods

2.1. Criteria for selecting studies

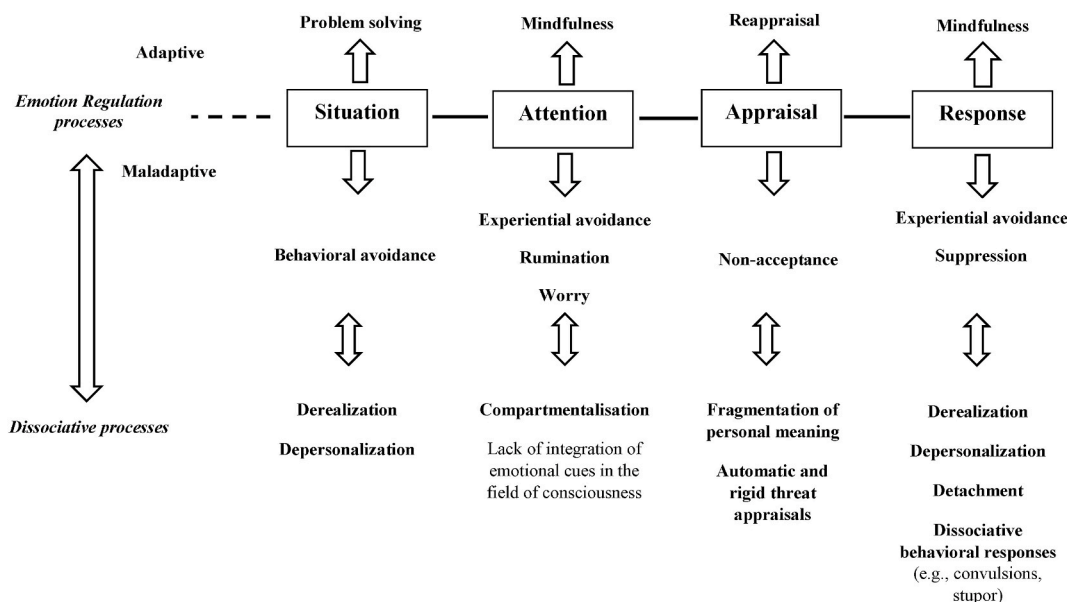The current meta-analytic review was conducted in line with Meta-

Fig. 1. An integrative model of emotion generation and regulation processes with dissociation.

Analysis Reporting Standards (MARS) of *American Psychological Association* (APA, 2008) and PRISMA guidelines (Moher et al., 2009).

Fig. 2 summarizes the inclusion process of studies. In order to consider studies of comparable quality, the analysis included only studies that were published on scientific journals. PsychINFo, Pubmed, ISI Web of Knowledge and Scopus online databases were used to generate potentially relevant articles. The online search was conducted for the period from 1974 to April 2020. The starting point was 1974 because this was the year when the first valid and reliable assessment tool for dissociation was published (Tellegen and Atkinson, 1974).

The online research was based on the following keywords: "dissociation", "dissociat* experiences", "dissociat* symptoms" AND "acceptance", "behavioral avoidance", "distraction", "experiential avoidance", "mindfulness", "nonacceptance", "problem-solving", "reappraisal", "rumination", "suppression", "thought suppression", "emotion* suppression", "worry". These key words were used in each online database. Key words related to emotion regulation processes were chosen according to a meta-analytic review on the structure of emotion regulation strategies (Naragon-Gainey et al., 2017).

M.C. and A.S. conducted the online research. The screening process was double-checked in order to produce a reliable initial sample of articles to consider for the inclusion in the meta-analysis. From the initial online research, M.C. and A.S. considered for the screening process all articles that showed, within the abstract section, at least an empirical evaluation of dissociative phenomenon or emotion regulation. Cohen's k was estimated for inter-rater reliability of studies selection (Cohen, 1960). In order to be included in the current meta-analytic review, the studies met the following inclusion criteria to support both the validity and the reliability of results: a) all studies evaluated dissociation using valid and reliable assessment instruments (i.e., self-report, diagnostic interviews) (see Tables 1 and 2); b) all studies referred to valid and reliable instruments for assessing emotion regulation strategies (i.e., self-report, experimental tasks) (see Table 1). Characteristics of samples (e.g., clinical vs. nonclinical), gender and research design were not considered exclusion criteria of the study. However, the analysis estimated their possible moderator effects on effect sizes.

2.2. Data analyses

The current meta-analysis was based on r coefficient as effect size measure. Values of r less than or equal to 0.10, 0.30, and 0.50 were interpreted as small, moderate, and large effect sizes, respectively (Cohen, 1992). When a study showed multiple correlations among outcomes, a single effect size was computed using procedures explained by Borenstein et al. (2011). The pooled effect size (r_w) and its 95% confidence interval (CI) were estimated referring to procedures described by Borenstein et al. (2011). Specifically, the correlation of each study is converted to the Fisher's z scale, which was used to perform all analysis. The summary effect and its confidence interval were then converted back to correlation for presentation of pooled effect size. The computation of overall pooled effect size for the strength of association between dissociation and emotion regulation was based on the absolute value of r coefficients. This approach was also adopted for the estimation of pooled effect sizes of subgroups with different sample characteristics (i.e., nonclinical, clinical). The computation of overall pooled effect size for the strength of association between dissociation and emotion regulation was based on the absolute value of r coefficient for each study. This approach was also adopted for the estimation of pooled effect sizes of subgroups with different sample characteristics (i. e., nonclinical, clinical). This meta-analysis was based on the estimation of random-effect models. The parameter T^2 was computed applying the DerSimonian and Laird method (1986).

Heterogeneity in effect sizes was computed using the Q statistic (Hedges and Olkin, 1985) and I^2 index (Higgins et al., 2003; Huedo-Medina et al., 2006a,b). Furthermore, meta-regression analysis was conducted in order to evaluate sources of heterogeneity across results of studies included in this work. Particularly, year of publication, sample size, age of participants, gender, continents where studies were carried out, research design (i.e., cross-sectional, longitudinal, experimental), characteristics of sample (i.e., nonclinical, clinical), and domains of emotion regulation strategies – disengagement (i.e., behavioral and attentional avoidance), aversive cognitive perseveration (i.e., over-engagement with negative cognitions and low tolerance of emotions) and adaptive (i.e., exposure-based attitudes towards emotional-eliciting stimuli and features of emotional response) – were introduced as independent variables in the meta-regression. Meta-regression analysis was also conducted separately considered each domain of emotion regulation.

Begg and Mazumdar (1994) rank correlation test and Egger's regression (1997) were estimated to detect publication bias. Bootstrap methodology (bias corrected and accelerated; Davison, 1997) was applied in computing the significance of the previous parameters. A total
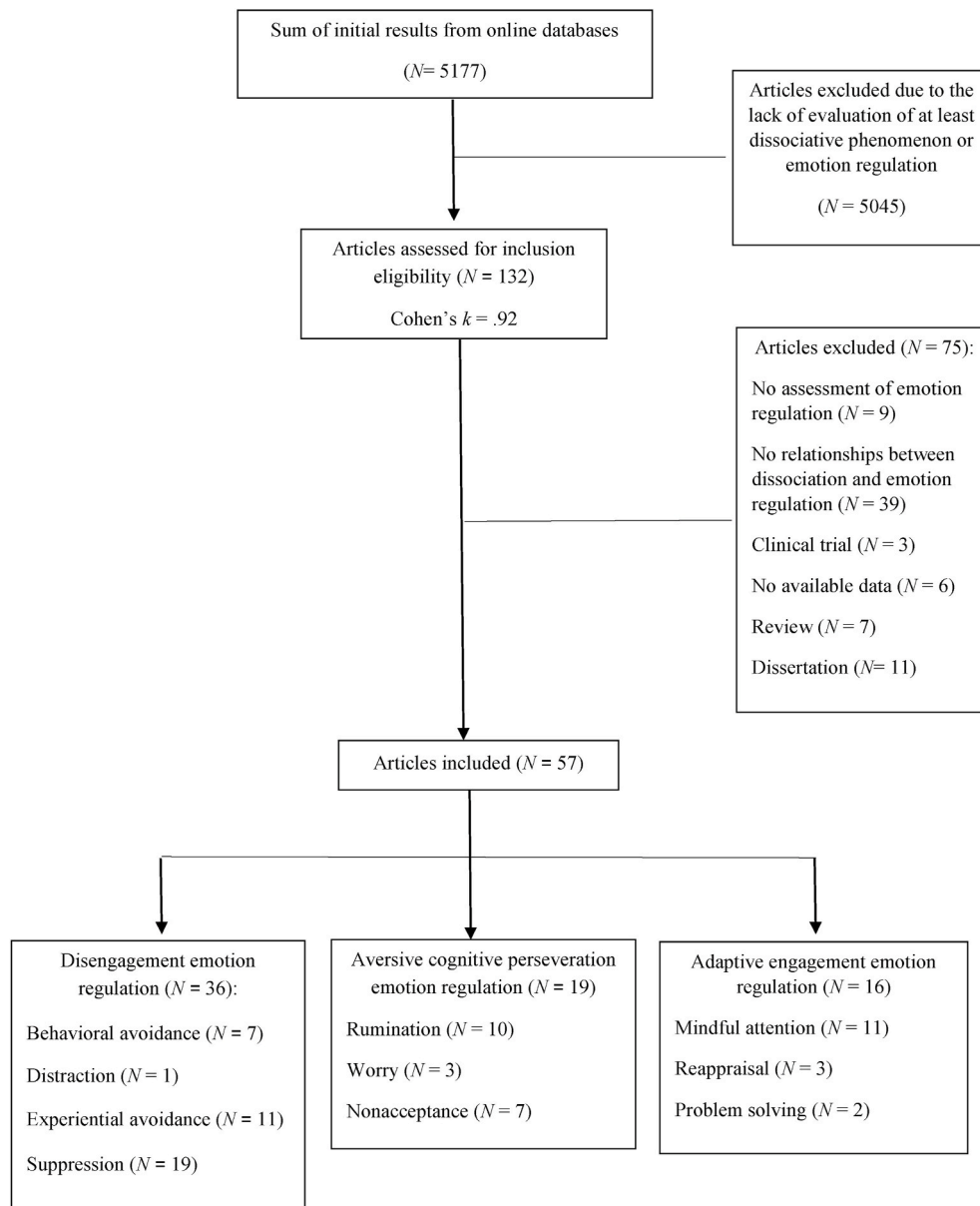
Fig. 2. CONSORT flow chart of studies inclusion process.

of 1000 bootstrap independent samples were used with $p < .05$ (2-*tailed*). Orwin's fail-safe procedure (1983) was estimated to assess the number of studies with null results needed to overturn meta-analytic conclusions. For Orwin's fail-safe *N*, the critical level was set at 0.10. In addition, it was computed the critical value ($5k + 10$; $k =$ number of studies) of Orwin's fail-safe *N* to evaluate the power of pooled effect sizes following procedures proposed by Rosenthal (1991).

Ultimately, according to the hypotheses of study, subgroup analyses were conducted based on the *Z*-test method in line with procedures proposed by Borenstein et al. (2011). The absolute value of pooled effect size for each subgroup was used for the contrasts. Bonferroni correction was applied when multiple comparisons were conducted. The results of Z-tests for detecting significant differences in pooled effect sizes were also corroborated by the estimation of the two one-sided tests procedure (Lakens, 2017; Schuirmann, 1987), which aim to evaluate equivalent effects between dissociation and emotion regulation processes among different subgroups. Specifically, the analysis was based on the application of procedures proposed by Rogers et al. (1993). Accordingly, the critical value for equivalence tests was set at ± 0.30, considering this

level as a lack of equivalent effects.

3. Results

Fig. 2 summarizes the inclusion process of studies. The analysis showed good inter-rater reliability values (Cohen's $k = 0.92$) for the screening of articles. Fifty-seven independent studies were included for a total of 11596 individuals. Table 1 and 3 provide a detailed description of characteristics of studies included in the meta-analysis. Table 4 includes results of meta-analytic procedures for each subgroup, according to the hypotheses of study.

3.1. The strength of association between dissociation and emotion regulation

Considering the absolute value, dissociation showed a moderate and significant relationship with emotion regulation ($r_w = 0.32$ [0.09 - 0.59]; $p < .05$), even though the heterogeneity across results was large ($I^2 = 79.58\%$) and significant ($Q_{(56)} = 274.24$; $p < .001$). Meta-regression

Table 1

Characteristics of studies assessing the association between dissociation and emotion regulation ($N = 57$ studies).

Study	Research design	Country	Sample size	Gender	Mean of age	Sample characteristics	Assessment of dissociation	Assessment of emotion regulation	r	Fisher's z (95% CI)
Baer et al. (2004)	Cross-sectional	USA	130	M + W	19.6	Nonclinical – Student	DES	KIMS	-.18	-.18 (−.35 to −.05)
Barlow & Goldsmith (2014)	Cross-sectional	USA	443	M + W	21.02	Nonclinical – Student	TSC-40 dissociation subscale	TCQ distraction, worry reappraisal	.18	.18 (.09–.28)
Bolduc et al. (2018)	Cross-sectional	Canada	234	M + W	38.7	Clinical – psychotherapy-seeking individuals	TSI-2	MAAS	-.45	-.48 (−.61 to −.25)
Boughner et al. (2016)	Cross-sectional	Canada	952	M + W	35.4	Trauma: mixed traumatic experiences	TRASC-Dissociation	FFMQ	-.28	-.28 (−.25 to −.22)
Butler et al. (2019)	Cross-sectional	Australia	194	M + W	31.55	Clinical (several psychiatric disorders) and general population	DES; SDQ-20	MAAS	-.52	-.57 (−.72 to −.43)
de Bruin et al. (2012)	Cross-sectional	Netherlands	451	M + W	20.7	Nonclinical – meditators vs non-meditators	DES	FFMQ	-.28	-.29 (−.28 to −.19)
Didonna et al. (2019)	Cross-sectional	Italy	202	M + W	37.5	Clinical (MDD, BPD, OCD) and HC	DES	FFMQ	-.63	-.74 (−.88 to −.60)
Dorahy et al. (2013)	Cross-sectional	Northern Irish	65	M + W	40.0	Trauma: conflict related	DES	CoSS – Avoidance subscale	.31	.32 (.07–.57)
Duckworth et al. (2000)	Cross-sectional	Canada	71	M + W	40.07	Clinical (chronic pain)	DES	MMPI-2 Social Introversion	.35	.36 (.13 - .60)
Engelhard et al. (2003)	Cross-sectional	Netherlands	126	W	31	Trauma: pregnancy loss	PDEQ	WBSI	.25	.25 (.08 - .43)
Escudero-Pérez et al. (2016)	Cross-sectional	Spain	55	M + W	38	Clinical – psychotic disorders	TAS; CDS	MAAS	-.55	-.62 (−.88 to −.35)
Fattahzadeh-Ardalani et al. (2017)	Case-control	Iran	240	M + W	Not reported	Clinical (Migraine headaches) vs HC	SDQ-20	QCS - Avoidance	.22	.22 (.09 - .35)
Giesbrecht et al. (2004)	Experimental	Netherlands	185	M + W	20.4	Nonclinical – students	DES	RNGT	.12	.12 (−.02 - .26)
Giesbrecht et al. (2006)	Cross-sectional	Netherlands	220	M + W	19.6	Nonclinical – students	DES	WBSI	.38	.40 (.27 - .53)
Hetzel-Riggin & Meads (2016)	Cross-sectional	USA	227	M + W	19.7	Trauma: mixed traumatic experiences	PDEQ	AAQ	.44	.47 (.34 - .60)
Hetzel-Riggin, & Wilber (2010)	Cross-sectional	USA	86	W	18.8	Trauma: sexual victimization	PEDQ	WBSI	.47	.51 (.29 - .72)
Iverson et al. (2013)	Longitudinal	USA	69	W	35.9	Trauma: Intimate partner violence	DES	PDS - effortful avoidance	.24	.24 (.003 - .29)
Jones et al. (2018)	Cross-sectional	USA	64	W	31.52	Trauma: sexual victimization	PEDQ	DERS Nonacceptance	.30	.31 (.06 - .56)
Kira et al. (2019)	Cross-sectional	Kuwait and Egypt	502	M + W	35.76	Trauma: war refugees	CTS-S dissociation subscale	ERQ suppression	.06	.06 (−.03 - .15)
Kumpula et al. (2011)	Longitudinal	USA	532	M + W	19.2	Nonclinical – students	PEDQ	AAQ-II	.36	.38 (.29 - .46)
Laposa & Rector (2012)	Experimental	Canada	91	W	20.57	Nonclinical – students	PEDQ	ARQ; RIQ	.28	.29 (.08 - .50)
Lee et al. (2015)	Cross-sectional	USA	213	M + W	20.77	Trauma: mixed traumatic experiences	PCL – emotional numbing	AAQ-II; ERQ-expressive suppression; KIMS – acceptance subscale; WBSI	.41	.44 (.30–57)
Mäirean & Ceobanu (2017)	Cross-sectional	Romania	148	M + W	21.19	Nonclinical – general population	DES	ERQ – expressive suppression; WBSI	.31	.33 (.16 - .49)
Marx & Sloan (2005)	Longitudinal	USA	185	M + W	19.6	Trauma: mixed traumatic experiences	PEDQ	AAQ	.25	.25 (.11 - .40)
Matos et al. (2013)	Cross-sectional	Portugal	90	M + W	29.5	Nonclinical – general population	DES	RRQ; WBSI	.48	.53 (.32–74)
Mazzoni et al. (2017)	Cross-sectional	Italy	535	M + W	27.1		CAS	MAAS	-.20	

Table 1 (*continued*)

Study	Research design	Country	Sample size	Gender	Mean of age	Sample characteristics	Assessment of dissociation	Assessment of emotion regulation	r	Fisher's z (95% CI)
						Nonclinical - general population				-.20 (−.30 to −.11)
Meyer et al. (2013)	Cross-sectional	USA	109	M + W	37.2	Trauma: Veterans	RAND-PDEQ	AAQ-II	.52	.58 (.38 - .77)
Meyer et al. (2019)	Longitudinal	USA	236	M + W	39.1	Trauma: Veterans	RAND-PDEQ	AAQ-II	.36	.38 (.25 - .50)
Muris & Merckelbach (1997)	Cross-sectional	Netherlands	54	M + W	20.9	Nonclinical – students	DES	WBSI	.35	.36 (.09 - .64)
Navarro-Haro et al. (2015)	Cross-sectional	Spain	91	M + W	27.5	Clinical – BPD and EDs	DES	ERQ suppression and reappraisal	.16	.16 (−.04 - .37)
Nestler et al. (2015)	Cross-sectional	UK	22	M + W	35.9	Clinical – Dissociative Disorders	DES	FMI	-.31	-.32 (−.77 - .13)
Perona-Garcelán et al. (2014)	Cross-sectional	Spain	318	M + W	21.41	Nonclinical – Students	TAS; CDS	SMQ	-.25	-.26 (−.37 to −.15)
Pinto-Gouveia et al. (2015)	Cross-sectional	Portugal	312	M + W	63.44	Trauma: veterans	PEDQ	AAQ-TS	.48	.53 (.41 - .63)
Pozza et al. (2018)	Cross-sectional	Italy	355	M + W	40.83	Nonclinical – general population	DES	AAQ-II	.25	.25 (.15 - .36)
Raudales et al. (2020)	Cross-sectional	USA	60	M + W	20.50	Clinical (marijuana user and insomnia)	RSDI - Dissociation	DERS Nonacceptance	.30	.31 (.05 - .57)
Reddy et al. (2015)	Experimental	USA	58	W	19.6	Trauma: mass shooting	PEDQ	AAQ-II; VAS suppression	.37	.39 (.12 - .65)
Regambal & Alden (2009)	Cross-sectional	Canada	148	M + W	20.23	Nonclinical – Students	PEDQ	RIQ	.31	.33 (.16 - .49)
Schlumpf et al. (2019)	Case-control	Switzerland	68	M + W	41.7	Clinical (DDs) vs HC	SCID-D	DERS nonacceptance; ERQ reappraisal	.58	.66 (.42 - .90)
Schönfeld & Ehlers (2006)	Experimental	UK	29	M + W	40.38	Clinical – PTSD patients	SDQ	RIQ	.49	.54 (.15 - .92)
Schurle Bruce et al., 2007	Case-control	USA	66	M + W		High dissociators vs low dissociators	DES	IGT	-.04	-.04 (−.29 - .20)
Schubert et al. (2018)	Cross-sectional	Australia	143	M + W	20.83	Nonclinical – students	ILQ - Absorption	RRQ	.13	.13 (-.09 – 29)
Selvi et al. (2012)	Cross-sectional	Turkey	95	M + W	27.8	Clinical – OCD	DES	WBSI	.43	.46 (.25 - .66)
Selvi et al. (2015)	Experimental	Turkey	32	M + W	25	Nonclinical – students	DES	WBSI	.21	.21 (−.15 - .68)
Spinhoven & van der Does (1999)	Cross-sectional	Netherlands	254	M + W	35.7	Clinical – mood and anxiety disorders; PTSD	DIS-Q; SDQ-5	WBSI	.23	.24 (.11 - .36)
Steffen et al. (2015)	Case-control	Germany	90	M + W	45	Clinical (DDs) vs HC	ICD-10 diagnosis	ERQ suppression	.38	.39 (.18 - .60)
Sundermann et al. (2013)	Cross-sectional	USA	89	W	30.7	Trauma: emotional, physical and sexual violence	DES	AAQ	.46	.50 (.28 - .71)
Tran et al. (2019)	Cross-sectional	USA	212	W	34.65	Trauma: intimate partner violence	DES	SPSI-R avoidant problem-solving	.43	.46 (.32 - .59)
van den Hout et al. (1996)	Cross-sectional	Netherlands	151	M + W	22.5	Nonclinical-Students	DES	WBSI	.52	.58 (.41 - .74)
Vannikov-Lugassi and Soffer-Dudek, 2018a	Cross-sectional	Israel	99	M + W	23.96	Nonclinical-Students	DES-II	RRS; AnTI	.19	.19 (−.007 - .39)
Vannikov-Lugassi & Soffer-Dudek, 2018b	Cross-sectional	Israel	94	M + W	24.09	Nonclinical-Students	DES-II	RRS	.34	.35 (.15 - .52)
Xavier et al. (2018)	Cross-sectional	Portugal	776	M + W	14.55	Nonclinical – adolescent	DES-A	AFQ-Y; RRS	.45	.49 (.42 - .56)
Walach et al. (2006)	Cross-sectional	Germany	287	M + W	39	Clinical (BPD), Meditators, General population	DES	FMI	-.28	-.29 (.17 - .40)
Wingenfeld et al. (2011)	Experimental	Germany	82	M + W	38.5	Clinical – psychosomatic patients	DES	ERQ suppression	.04	.04 (−.18 - .26)
Wolfradt & Engelmann (1999)	Cross-sectional	Germany	200	M + W	40.3	Clinical – AnxD; MDD; Sch	QED	SPQ	.45	.48 (.34 - .62)
Wong et al. (2006)	Cross-sectional	USA	30	M + W	28	Clinical - patient with cancer	PEDQ		.23	.23 (−.14 - .61)

Table 1 (*continued*)

Study	Research design	Country	Sample size	Gender	Mean of age	Sample characteristics	Assessment of dissociation	Assessment of emotion regulation	r	Fisher's z (95% CI)
								Brief COPE – Avoidance and Distraction		
Yıldırım et al. (2018)	Cross-sectional	Turkey	85	M + W	31.19	Nonclinical - health staff	DES	PSWQ	.55	.62 (.40 - .83)
Yoshizumi & Murase (2007)	Cross-sectional	Japan	641	M + W	20	Nonclinical-Students	DES	NRTS; WBSI	.33	.34 (.26 - .42)

AAQ = Acceptance and Action Questionnaire (Hayes et al., 2004); AAQ-II = Acceptance and Action Questionnaire-II (Bond et al., 2011); AAQ-TS = Acceptance and Action Questionnaire-Trauma Specific (Pinto-Gouveia et al., 2015); AFQ-Y = Avoidance and Fusion Questionnaire for Youth (Greco et al., 2008); AnTI = Anxious Thoughts Inventory (Wells, 1994); AnxD = Anxiety Disorders; ARQ = Anxious Rumination Questionnaire (Rector et al., 2008); BPD = Borderline Personality Disorder; Brief COPE (Carver, 1997); CAS = Cognitive Absorption Scale (Agarwal and Karahanna, 2000); CDS = Cambridge Depersonalization Scale (Sierra and Berrios, 2000); CoSS = Compass of Shame Scale (Elison et al., 2006); CTS-S = Cumulative Trauma Scale Short form (Kira et al., 2019); DDs = Dissociative Disorders; DERS = Difficulties in Emotion Regulation Scale (Gratz and Roemer, 2004); DES = Dissociative Experiences Scale (Bernstein and Putnam, 1986); DES-II = Dissociative Experiences Scale-II (Carlson and Putnam, 1993); DES-A = Dissociative Experiences Scale – Adolescent (Armstrong et al. 1997); DIS-Q = Dissociation Questionnaire (Vanderlinden et al., 1993); EDs = Eating Disorders; ERQ = Emotion Regulation Questionnaire (Gross and John, 2003); FFMQ = Five Facet Mindfulness Questionnaire (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2003); FMI = Freiburg Mindfulness Inventory (Walach et al., 2006); HC = Healthy Controls; ILQ = Intellectance and Liberalism Questionnaire (Glisky and Kihlstrom, 1993); IGT = IOWA Gambling Task (Bechara et al., 1994); KIMS = Kentucky Inventory of Mindfulness Skills (Baer et al., 2004); MAAS = Mindful Attention Awareness Scale (Brown and Ryan, 2003); MMD = Major Depressive Disorder; MMPI-2 = Minnesota Multiphasic Personality Inventory-2 (Butcher et al., 1989); NRTS = Negative Rumination Trait Scale (Ito and Agari, 2001); OCD = Obsessive-Compulsive Disorder; PCL = PTSD Checklist (Weathers et al., 1993); PDEQ = Peritraumatic Dissociative Experiences Questionnaire (Marmar et al., 1997); PDS = Posttraumatic Diagnostic Scale (Foa et al., 1997); PSWQ = Penn State Worry Questionnaire (Meyer et al., 1990); PTSD = Post-Traumatic Stress Disorder; QCS = Questionnaire of Coping Strategies (Namir et al., 1987); QED = Questionnaire of Experiences of Dissociation (Riley, 1988); RAND-PDEQ = RAND Peritraumatic Dissociative Experiences Questionnaire (Marshall et al., 2002); RNGT = Random Number Generation Task (Miyake et al., 2000); RSDI = Responses to script-driven imagery scale (Hopper, Frewen, van der Kolk and Lanius, 2007); RIQ = Response to Intrusions Questionnaire (Clohessy and Ehlers, 1999); RRQ = Rumination Responses Questionnaire (Treynor et al., 2003); RRS = Ruminative Response Scale; Sch = Schizophrenia; SDQ = State Dissociation Questionnaire (Murray et al., 2002); SDQ-5 = Somatoform Dissociation Questionnaire-5 (Nijenhuis et al., 1997); SDQ-20 = Somatoform Dissociation Questionnaire-20 (Nijenhuis et al., 1996); SMQ = Southampton Mindfulness Questionnaire (Chadwick et al., 2008); SPQ = Stress-Process Questionnaire (Janke et al., 1985); SPSI-R = Social Problem-Solving Inventory–Revised (D'Zurilla et al., 1996); TAS = Tellegen Absorption Scale (Tellegen and Atkinson, 1974); TCQ = Thought Control Questionnaire (Wells and Davies, 1994); TRASC = trauma-related altered states of consciousness; TSC-40 = Trauma Symptom Checklist (Briere and Runtz, 1989); TSI-2 = Trauma Symptom Inventory-2 (Briere, 2011); VAS = Visual Analogue Scale; WBSI = White Bear Suppression Inventory (Wegner and Zanakos, 1994).

analysis highlighted that variables included in the model did not significantly predict the variability of effect sizes ($R^2 = 0.22$; $F_{(12, 44)} = 1.01$; *ns*). The analyses did not detect bias of publication (see Table 4). However, the Orwin's fail-safe number was lower than Rosenthal's critical value (see Table 4).

3.2. Dissociation and emotion regulation among different samples

The strength of association between dissociation and emotion regulation was moderate for nonclinical samples ($r_w = 0.32$ [0.13–54]; $p < .01$). Patients affected from psychiatric disorders and other medical conditions reported a moderate association between dissociation and emotion regulation ($r_w = 0.37$ [0.13–0.61]; $p < .001$). Heterogeneity of findings was large and significant for all subgroups (see Table 4). Bias of publication was not detected for these subgroups (see Table 4). The analysis did not detect a significant difference in the strength of association between dissociation and emotion regulation among clinical and nonclinical samples (Z clinical vs nonclinical = 0.33; *ns*). Furthermore, the equivalence test showed same pooled effect sizes among these samples ($Z_{upper} = 2.18$, $p < .05$; $Z_{lower} = -1.51$, $p = .06$).

3.3. Dissociation and different domains of emotion regulation

Meta-analytic procedures showed moderate associations between dissociation and different domains of emotion regulation, namely disengagement ($r_w = 0.34$ [0.10 - 0.57]; $p < .01$), aversive cognitive perseveration ($r_w = 0.38$ [0.21 - 0.55]; $p < .001$). Conversely, this evidence was not replicated for the adaptive engagement domain ($r_w = -0.21$ [-0.59 - 0.17]; *ns*). The heterogeneity of results across studies was large and significant for all subgroups (see Table 4). Bias of publication was not detected (see Table 4). On the one hand, the Z-tests did not support significant differences in the strength of association between dissociation and different domains of emotion regulation (Z cognitive

perseveration vs adaptive = .89, *ns;* Z disengagement vs adaptive = .56, *ns;* Z cognitive perseveration vs disengagement = 0.37, *ns*). On the other hand, the equivalence tests highlighted same effects for the relationship between dissociation and maladaptive domains of emotion regulation (cognitive perseveration vs disengagement: $Z_{upper} = 2.89$, $p < .01$; $Z_{lower} = -2.14$, $p < .05$), but not when maladaptive domains were compared to adaptive one (cognitive perseveration vs adaptive: $Z_{upper} = .66$, *ns*; $Z_{lower} = -2.45$, $p < .01$; disengagement vs adaptive: $Z_{upper} = .77$, *ns*; $Z_{lower} = -1.88$, $p < .05$). Fig. 2 graphically summarizes these findings.

3.4. Dissociation and disengagement domain of emotion regulation

The disengagement domain of emotion regulation strategies includes behavioral avoidance, experiential avoidance together with thought and emotional suppression. These emotion regulation strategies cover at least three stages of emotion generation, namely situation, attentional processes and emotional responses (see Fig. 1) Behavioral avoidance ($r_w = 0.36$ [0.19 - 0.53]; $p < .01$), experiential avoidance ($r_w = 0.42$ [0.24 - 0.60]; $p < .001$) and thought suppression ($r_w = 0.37$ [0.22 - 0.52]; $p < .001$) showed moderate to large associations with dissociation. On the contrary, emotional suppression ($r_w = 0.23$ [-0.12 - 0.57]; *ns*) highlighted a nonsignificant small to moderate relation with dissociation. The heterogeneity of results ranged from moderate to large for all subgroups (see Table 4).

The meta-regression analysis showed that sources of heterogeneity did not predict the variability of findings across studies ($R^2 = 0.10$; $F_{(9, 26)} = 0.32$; *ns*). However, the analyses did not reveal bias of publication (see Table 4). The analyses based on the Z-tests did not detect significant differences among pooled effect sizes constituting the disengagement domain. Equivalent effects were found comparing the pooled effect sizes of behavioral avoidance, experiential avoidance and thought suppression. On the contrary, the pooled effect size capturing the relationship between dissociation and emotional suppression was not equal to the

Table 2
Assessment and operationalization of dissociation.

Instrument	Theoretical background	Content of items	Item examples
Dissociative Experiences Scale	DSM criteria for dissociative disorders	Trait measure that assesses percentage of the time subjects experience dissociative symptoms: dissociative amnesia (e.g., memory loss), absorption (e.g., being so preoccupied or absorbed by something that you are distracted from what is going on around you), depersonalization/derealization (e.g., feeling detached from one's self and mental processes or a sense of unreality of the self)	"Some people find that they become so involved in a fantasy or daydream that it feels as though it were really happening to them" "Some people have the experience of finding themselves dressed in clothes that they don't remember putting on" "Some people have the experience of looking in a mirror and not recognizing themselves"
Trauma Symptom Checklist 40 – dissociation subscale	Symptoms linked to exposure of sexual-abuse trauma	Trait measure that evaluates how often subjects experience dissociative symptoms	How often have you experienced each of the following in the last two months? "Flashbacks" (sudden, vivid, distracting memories) "Spacing out" (going away in your mind) "Dizziness" "Memory problems" "Feeling that things are "unreal"" "Feelings that you are not always in your body"
Trauma Symptom Inventory 2 – dissociation subscale	DSM criteria for post-traumatic stress disorder	Trait measure that evaluates how often subjects experience dissociative symptoms	Protected by copyright
Dissociation – Trauma-related altered states of consciousness	4-D model of trauma-related altered states of consciousness (i.e., temporal-memory, cognitive, bodily, emotional disturbance)	Items assess dissociative several dissociative phenomena — depersonalization, derealization, dissociative flashback, thought in second-person perspective, feeling of being numbing	"Feeling detached or separated from your body, for example, feeling like you are looking down on yourself from above, or like you are an outside observer of your own body." "Feeling completely numb, hollow, and lifeless inside, as if you are already dead"
Somatoform Dissociation Questionnaire-20	Theory of structural dissociation of the personality	Items evaluate the severity of somatoform manifestations of dissociation of the personality	Please indicate to what extent these experiences apply to you in the past year. "I have an attack that resembles an epileptic seizure" "I am paralyzed for a while" "My body, or a part of it, is insensitive to pain"
Peritraumatic Dissociative Experiences Questionnaire	Theoretical and empirical evidence related to etiology of PTSD	Items assess dissociative experiences during a traumatic event or shortly thereafter — altered awareness, depersonalization/derealization	"My sense of time changed—things seemed to be happening in slow motion" "What was happening seemed unreal to me, like I was in a dream or watching a movie or play" "I felt as though I was a spectator watching what was happening to me" "There were moments when my sense of my own body seemed distorted or changed"
Tellegen Absorption Scale	Hypnotic susceptibility	Items capture the disposition for having episodes of "total" attention that fully engage one's representational (i.e., perceptual, enactive, imaginative, and ideational) resources	"I like to watch cloud shapes change in the sky"
Cambridge Depersonalization Scale	Descriptive psychopathology of depersonalization	The scale captures the frequency and duration of depersonalization symptoms	This questionnaire describes strange and 'funny' experiences that normal people may have in their daily life. We are interested in their: a) frequency, i.e. how often have you had these experiences OVER THE LAST SIX MONTHS; and b) their approximate duration. For each question, please circle the answers that suit you best. If you are not sure, give your best guess. "Out of the blue, I feel strange, as if I were not real or as if I were cut off from the world" "Parts of my body feel as if they didn't belong to me" "Whilst doing something I have the feeling of being a 'detached observer' of myself"
Cumulative Trauma Scale Short form – dissociation subscale	Symptoms profile frequently reported by torture survivors and refugee	The subscale measures the severity of dissociative symptoms associated to cumulative traumatic experiences.	"I believe I have enemies that follow me anywhere I go" "I sometimes her voices or things people do not see or hear" "I sometimes feel if I am almost two different people"
PTSD Checklist – emotional numbing subscale	DSM criteria for PTSD	The scale assesses the severity of emotional numbing symptoms ascribed to criteria D of PTSD	Below is a list of problems and complaints that veterans sometimes have in response to stressful life experiences. Please read each one carefully, put an "X" in the box to indicate how much you have been bothered by that problem in the last month "Feeling distant or cut off from other people?" "Feeling emotionally numb or being unable to have loving feelings for those close to you?" "Feeling as if your future will somehow be cut short?"

Table 2 (*continued*)

Instrument	Theoretical background	Content of items	Item examples
Cognitive Absorption Scale	Revision of different theoretical and empirical approaches to cognitive absorption	The scale captures different features of cognitive absorption – temporal dissociation, focused immersion, heightened enjoyment, control, curiosity	"Time appears to go very quickly" "Sometimes I lose track of time"
RAND Peritraumatic Dissociative Experiences Questionnaire	Theoretical and empirical evidence related to etiology of PTSD	Items assess dissociative experiences during a traumatic event or shortly thereafter for subjects with low levels of education	"Blanked out" "Did not seem real" "Felt confused"
Responses to script-driven imagery scale – Dissociation items	Items were adapted from Peritraumatic Dissociative Experiences Questionnaire	Items evaluate the severity of dissociative reactions to script-driven imagery responses - depersonalization and derealization	"Did what you were experiencing seem unreal to you, like you were in a dream or watching a movie or play?" "Did you feel disconnected from your body?" "Did you feel like you were in a fog?"
Intellectance and Liberalism Questionnaire – Absorption subscale	Hypnotic susceptibility, adapted from Tellegen Absorption Scale	Items capture the disposition for having episodes of "total" attention that fully engage one's representational (i.e., perceptual, enactive, imaginative, and ideational) resources	"It is sometimes possible for me to be completely immersed in nature or in art and to feel as if my whole state of consciousness has somehow been temporarily altered" "Sometimes thoughts and images come to me without the slightest effort on my part"
ICD-10 Dissociative Disorders	Pathological dissociation	Dissociative seizures Dissociative motor disorder/Dissociative movement disorder Dissociative anesthesia and sensory loss/ dissociative sensitivity disorder Multiple dissociative movement and sensitivity disorders	ICD-code F44.5 ICD-code F44.4 ICD-code F44.6 ICD-code F44.7
Questionnaire of Experiences of Dissociation	Dissociation as a spectrum from normal to pathological phenomena	Items cover normal and pathological dissociative experiences - depersonalization, process amnesia, fantasy/daydream, dissociated body behavior, trance	"feel like someone else" "mind goes blank" "daydreamed in school as child" "someone inside tells me what to do" "gone into trance"

associations with behavioral avoidance ($Z_{upper} = -.86$, *ns*; $Z_{lower} = 2.19$, $p < .05$), experiential avoidance ($Z_{upper} = -0.55$, *ns*; $Z_{lower} = 2.46$, $p < .01$) and thought suppression ($Z_{upper} = -0.81$, *ns*; $Z_{lower} = 2.31$, $p < .05$).

3.5. Dissociation and aversive cognitive perseveration domain of emotion regulation

Aversive cognitive perseveration domain refers to rumination, worry and nonacceptance. These emotion regulation strategies affect two main mechanisms involved in emotion generation, namely attentional processes and cognitive appraisal (see Fig. 1). Dissociation showed moderate to large associations with rumination ($r_w = 0.35$ [0.23 - 0.47]; $p < .001$), worry ($r_w = 0.39$ [0.14 - 0.44]; $p < .01$) and nonacceptance ($r_w = 0.40$ [0.17 - 0.44]; $p < .01$), even though the heterogeneity of findings was significant for these emotion regulation strategies. Variables included in the meta-regression did not explain the variability of results

Table 3
Descriptive statistics ($N = 57$).

Variable	N	%
Men + Women	49	86.0
Women	8	14.0
Europe	27	47.4
North America	20	35.1
Africa	7	12.3
Oceania	2	3.5
Asia	1	1.8
Cross-sectional studies	45	79.0
Experimental studies	8	14.0
Longitudinal studies	4	7.0
Nonclinical samples	39	68.5
Clinical samples	18	31.5
Disengagement	27	47.4
Aversive cognitive perseveration	5	8.8
Disengagement + aversive cognitive perseveration	6	10.5
Adaptive engagement	11	19.3
Adaptive engagement + aversive cognitive perseveration	5	8.8
Adaptive Engagement + disengagement + aversive cognitive perseveration	3	5.3

across studies ($R^2 = 0.34$; $F_{(7, 10)} = 0.74$; *ns*). Bias of publication was not detected (see Table 4). Furthermore, the Z-tests ($Z_{rumination\ vs\ worry} = 0.27$, *ns*; $Z_{rumination\ vs\ nonacceptance} = .39$, *ns*; $Z_{worry\ vs\ nonacceptance} = .07$; *ns*) for detecting significant differences among effect sizes together with equivalence tests ($1.79 = Z_{upper} \leq 2.63$, $0.01 < p < .05$; $-1.84 = Z_{lower} \leq -1.65$, $p < .05$) suggested that relationships between dissociation and specific mechanisms related to aversive cognitive domain of emotion regulation were the same.

3.6. Dissociation and adaptive engagement domain of emotion regulation

Adaptive engagement domain includes mindfulness and reappraisal emotion regulation strategies. These emotion regulation strategies impact emotion generation through attentional processes, cognitive appraisal and response modulation (see Fig. 1). The negative associations between dissociation with mindfulness ($r_w = -0.22$ [-0.61 - 0.17]; *ns*) and reappraisal ($r_w = -0.18$ [-0.70 - 0.34]; *ns*) were small to moderate, albeit nonsignificant. The heterogeneity of results was large and significant for these emotion regulation strategies (see Table 4). Meta-regression model did not predict the variability of findings ($R^2 = 0.56$; $F_{(5, 10)} = 2.55$; *ns*). The analysis did not find bias of publication (see Table 4). Despite the Z-test did not highlight significant differences between the previous pooled effect sizes ($Z = 0.12$; *ns*), the equivalence test showed that dissociation had not the same relationship with mindfulness and reappraisal ($Z_{upper} = 1.03$, *ns*; $Z_{lower} = -0.78$, *ns*) (see Fig. 3 for a graphical summary of meta-analytic results).

4. Discussion

This study sought to comprehensively summarize empirical evidence concerning the role of dissociation within emotion regulation using a meta-analytic approach. The main aim of the current review was to propose a model that clarifies the relationships between dissociative phenomena and different emotional regulatory strategies. Overall, the meta-analytic results showed three main findings: i) dissociation was moderately associated to emotion regulation; ii) dissociation showed more robust relationships with maladaptive domains of emotion

Table 4
The extent of relationships between dissociation and emotion regulation.

	N studies	N subjects	r_w	T (95% CI$_{rw}$)	fail-safe N (critical value)	Q (df)	I^2	r_{B-M} (bootstrap 95% CI)	Egger's coefficient (bootstrap 95% CI)
Overall	57	11596	.32*	.12 (.09 - .56)	140.18 (295.0)	274.24 $_{(56)}$***	79.58%	-.12 (−.29 - .04)	-.35 (−1.05 - .35)
Nonclinical sample	39	8535	.32**	.11 (.13 - .54)	53.20 (125.0)	164.00 $_{(38)}$***	76.83%	-.17 (−.49 - .16)	-.98 (−1.78 - .98)
Clinical samples	18	2384	.37**	.12 (.13 - .61)	48.75 (90.0)	64.14 $_{(17)}$***	73.49%	-.26 (−.59 - .07)	-.77 (−3.78 − .35)
Disengagement emotion regulation	36	7261	.34**	.12 (.10 - .57)	92.94 (190.0)	168.34 $_{(35)}$***	79.20%	-.16 (−.41 - .10)	-.35 (−1.89 - .53)
Behavioral avoidance	7	887	.36**	.08 (.19 - .53)	19.02 (45.0)	12.85 $_{(6)}$*	53.31%	-.33 (−1.00 - .81)	−1.21 (−2.98 - 1.35)
Suppression	19	3110	.30***	.08 (.17 - .43)	41.52 (105.0)	34.89 $_{(18)}$**	48.42%	.00 (−.36 - .38)	.55 (−1.08 - 2.39)
Thought suppression	13	2168	.37***	.08 (.22 - .52)	37.07 (75.0)	27.13 $_{(12)}$**	55.76%	.00 (−.48 - .53)	.72 (−1.38 - 2.38)
Emotional suppression	8	1303	.23	.18 (−.12 - .57)	12.45 (50.0)	46.49 $_{(12)}$***	84.94%	.07 (−.68 - .84)	1.23 (−7.28 − 6.36)
Experiential avoidance	11	3092	.42***	.09 (.24 - .60)	36.45 (65.0)	43.60 $_{(10)}$***	77.60%	-.28 (−.89 - .35)	−2.59 (−5.43 − 2.98)
Aversive cognitive perseveration emotion regulation	19	4849	.38***	.09 (.21 - .55)	56.52 (105.0)	66.68 $_{(18)}$***	73.00%	-.16 (−.48 - .16)	-.57 (−1.87 − .62)
Nonacceptance	7	2010	.40**	.12 (.17 - .64)	22.77 (45.0)	37.19 $_{(6)}$***	83.86%	-.19 (−1.00 - .65)	-.43 (−4.42 - 4.12)
Rumination	10	2311	.35***	.06 (.23 - .47)	25.72 (60.0)	17.76 $_{(9)}$*	49.33%	-.02 (−.55 - .50)	.57 (−5.03 − 3.46)
Worry	3	627	.39**	.12 (.14 - .64)	9.09 (25.0)	8.94 $_{(2)}$*	77.63%	-	-
Adaptive engagement emotion regulation	16	4233	-.21	.19 (−.59 - .17)	23.60 (90.0)	185.60 $_{(15)}$***	91.91%	.02 (−.41 - .39)	1.59 (−2.45 − 4.93)
Mindful attention	11	2845	-.22	.21 (−.61 - .17)	16.82 (60.0)	147.67 $_{(9)}$***	93.90%	.20 (−.60 - .81)	3.40 (−2.74 - 10.61)
Reappraisal	3	602	-.18	.26 (−.70 - .34)	4.09 (25.0)	29.21 $_{(2)}$***	93.15%	-	-

*$p < .05$; **$p < .01$; ***$p < .001$; TEs = Traumatic Experiences.
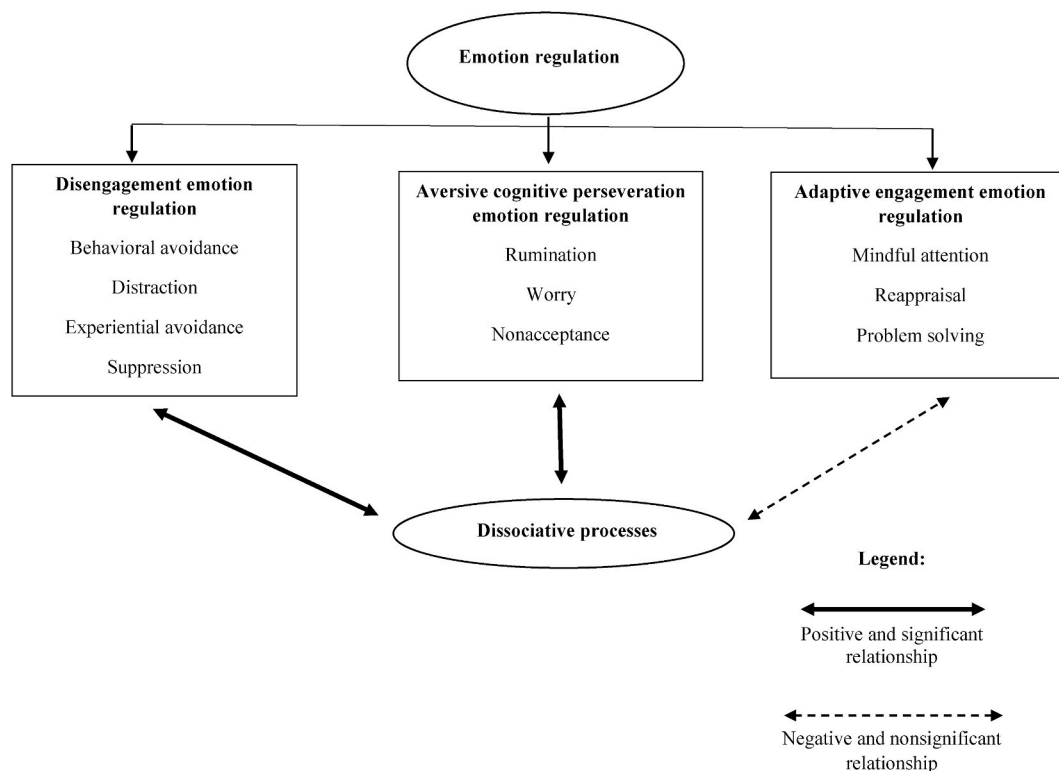
Fig. 3. The relationships between dissociative mechanisms and emotion regulation.

regulation than adaptive one; iii) dissociation highlighted significant and consistent relationships with all maladaptive emotion regulation strategies along the stages of emotional generation.

The overall pooled effect size suggested a moderate and significant association between dissociation and emotion regulation processes. This evidence was in line with several clinical and neurobiological models (e. g., Scalabrini et al., 2020a; Lanius et al., 2010; Mucci, 2018; Mucci and Scalabrini, 2021; Schore, 2009) that have viewed dissociative phenomena with a regulatory function of affective states. Taking into account the non-voluntary nature of dissociative phenomena (World Health Organization, 2018), the significant association between dissociation and emotion regulation might reflect automatic mechanisms involved in modulating emotional reactions, which were demonstrated by neurobiological models of emotion regulation (e.g., Braunstein et al., 2017).

The moderate effect size between dissociation and emotion regulation was not surprising. The strength of this association might be interpreted considering together several features characterizing both dissociation and emotion regulation. First, it is well-accepted that dissociation affects not only emotions, but also several other domains of mental functioning — memory, identity, time perception, thought, and body representation (e.g., APA, 2013; Lanius, 2015) — operating out of the field of consciousness resulting in a subconscious psychological automatism. Secondly, there is consistent evidence that demonstrated how emotion regulation is largely based on conscious and controlled higher-order cognitive processes considering both psychological and neurobiological models (Braunstein et al., 2017). These considerations might provide an explanation for the moderate overlap between dissociation and emotion regulation.

The analysis did not find a significant effects of sample characteristics on the overall relationship between dissociation and emotion regulation, although clinical samples showed slightly more robust associations (i.e., moderate to large effect sizes) than nonclinical ones (i.e., moderate effect size). This result suggests that dissociative phenomena might significantly interfere with adaptive emotional regulatory functioning of individuals. The maladaptive nature of dissociative phenomena within the context of emotion regulation is in line with empirical data that demonstrated an incremental severity of dissociation across different forms of psychopathology, identifying a dissociative continuum at the base of mental disorders (Lyssenko et al., 2018).

However, meta-analytic results also showed a moderate and significant relationship between dissociation and emotion regulation among nonclinical subjects, which did not differ from clinical samples. This finding might sustain two main considerations. First, the significant and moderate pooled effect size among general population is consistent with conceptualizations of dissociation as a dimension that ranges from milder forms with no or minimal interference on adaptation (Ray, 1996) probably with a genetic base (Koenen et al., 2005; Pieper et al., 2011), to pathological pervasive forms. Accordingly, the role of dissociation within emotion regulation might be wired in the neuronal functioning of the brain as suggested by several empirical findings concerning the existence of specific dissociative-related brain circuits involved in integrating internal-external stimuli (e.g., anterior insula) (Harricharan et al., 2020) and high-intensity emotional situations (e.g., amygdala, hippocampus, parahippocampal gyrus and middle/superior temporal gyrus) (Krause-Utz et al., 2014), together with shutdown emotional arousal (e.g., excessive corticolimbic inhibition) (Lanius et al., 2010; Nicholson et al., 2020).

The maladaptive function of dissociation found a further support considering pooled effect sizes related to the three domains of emotion regulation. Specifically, dissociation showed moderate to large associations with disengagement and aversive cognitive perseveration factors. On the contrary, the analyses highlighted negative and nonsignificant relationships between dissociation and adaptive emotion regulation strategies.

The maladaptive consequences of dissociation on emotion regulation might be linked to automatized, non-voluntary and inflexible internal-external escape reactions (Lanius et al., 2010) from emotional-eliciting situations and affective responses. This form of avoidance does not allow to process and integrate within the field of consciousness features of internal and external reality with an emotional relevance (Foa and Hearst-Ikeda, 1996; Haaland and Landrø, 2009) together with an engagement in effective long-term cognitive and behavioral responses to personal and environmental demands (Chawla and Ostafin, 2007). Accordingly, meta-analytic results showed moderate to large associations between dissociation and behavioral/experiential avoidance.

In addition to an avoidance function, neuroscience data might suggest that maladaptive effects of dissociation on emotion regulation are linked to a form of over-modulation of affective states on base of a heightened activity of brain regions (i.e., dorsal anterior cingulate cortex and the medial prefrontal cortex) (Lanius et al., 2010) involved in self-regulation of emotions (Ochsner et al., 2012). According to this notion, the current meta-analytic results showed moderate to large relationship between dissociation and thought suppression, which captures the tendency in rigidly using several cognitive processes (e.g., monitoring, suppression) to prevent distressing thoughts from entering in the field of consciousness (Wenzlaff and Wegner, 2000), which paradoxically increase the intensity and duration of negative affectivity (Abramowitz et al., 2001; Borton et al., 2005). Similarly, dissociation highlighted moderate to large associations with emotion regulation strategies ascribed to the aversive cognitive perseveration domain — non-acceptance, rumination and worry. These results might provide a support for the conceptualization of dissociation also as an automatized maladaptive form of over-control of emotional reactions. Indeed, it is well-recognized that emotion-based repetitive thought patterns, such as rumination and worry, together with rigid judgmental attitude towards emotional states represent intrusive and not fully deliberate phenomena that attempt to cognitively control emotional responses (e.g., Lanius, 2015; Perrin and Last, 1997; Treynor et al., 2003). These mechanisms cause maladaptive effects on emotional functioning interfering with the development of a balanced selection of different emotion regulation strategies (Sheppes et al., 2015).

4.1. Limitations

Despite the evidence discussed above, some limitations must be mentioned. The primary limitation was the correlation approach of studies included in the current meta-analysis. Despite theoretical frameworks and empirical evidence suggested reciprocal influences between dissociative and emotion regulation processes, it would be useful at a conceptual level to clarify the direction of causality between these mechanisms. Indeed, it was shown that the onset of early dissociative phenomena interferes with the development of adaptive emotion regulation strategies and facilitates the use dysfunctional emotion regulation processes (Macfie et al., 2001; Putnam, 1996). However, other evidence highlighted that the early expression of maladaptive emotion regulation strategies represents a significant risk factor for the development of dissociative symptoms (e.g., Briere, 2006; Chaplo et al., 2015; Powers et al., 2015). Therefore, future empirical research should assume a development perspective moving towards longitudinal studies in order to effectively evaluate the nature of relationships between dissociation and emotion regulation processes.

The correlation approach also represented a limitation at a meta-analytic level. Despite the current work included a considerable number of independent studies, this was not enough to conduct more appropriate statistical analysis to study the structure of correlations between dissociation and different domains of emotion regulation, such as factor analytic procedures and network analysis (Epskamp et al., 2018; Wolf et al., 2013). Therefore, the current comprehensive model that includes dissociation as a relevant dimension within emotion regulation processes should be empirically evaluated among large samples composed of nonclinical and clinical subjects, applying the

previous data analysis techniques for effectively estimating functional relationships between these mechanisms. Considering network analysis, this statistical approach could also provide a method to investigate the direction of causality between dissociative phenomena and emotion regulation strategies (e.g., Doreian, 2001; McNally, 2016).

An additional limitation of this study was the large heterogeneity across results, which was not explained by several sources of variability included in the meta-regression. This finding might suggest the hypothesis concerning not linear associations between automatic dissociative mechanisms and emotion regulation. Specifically, nonlinear relationships could be explained by a gradient of pervasiveness of these mechanisms on mental functioning together with a level of inflexibility across different situations. This consideration might be partially consistent with empirical evidence showed by the meta-analysis conducted by Lyssenko et al. (2018) on the role of dissociation among psychopathological disorders. On the one hand, the link between dissociation and clinical conditions linearly increases from affective, anxiety, substance use and personality disorders, especially borderline personality disorder. On the other hand, dissociative disorders seemed to clearly distinguish themselves from the other diagnostic categories in terms of the strength of association between dissociative mechanisms and clinical features of these conditions.

The values of Orwin's fail-safe number were smaller than Rosenthal's critical value suggested possible publication bias (Becker, 2005) related to the *file-drawer problem* (Rosenthal, 1979) reflecting the fact that studies with statistically significant results are more likely to be published than those with non-significant results. Despite the large number of studies included in the current meta-analysis, further methodologically robust studies (e.g., laboratory paradigms) should explore the relationships between dissociation and emotion regulation and their results should be published independently of significance in order to provide definitive conclusions about this topic.

The last limitation of the current meta-analysis refers to the assessment procedures. Indeed, dissociation and emotional regulation were assessed through the use of self-report instruments. Despite their psychometric properties, adequate structured clinical interviews, such as SCID-D (Structured Clinical Interview for DSM-IV Dissociative Disorders Interview; Steinberg, 1993; 1994) and DDIS (Dissociative Disorders Interview Schedule; Ross et al., 1989), are well-recommended for a comprehensive assessment of dissociative phenomena, especially for maladaptive ones (Steinberg, 1996). Furthermore, considering the automatic and non-voluntary nature of dissociative mechanisms, the link between emotion regulation and dissociation should be also supported by implicit measures. Specifically, psychophysiological indexes (e.g., heart rate variability, skin conductance response) might clarify the impact of dissociative mechanisms on emotional functioning (e.g., Barnow et al., 2012; Griffin et al., 1997; Williams et al., 2003). Moreover, the evaluation of dissociation and its effects on emotion regulation processes should be corroborated through specific experimental paradigms using different behavioral and neuroimaging methods to investigate the impact of dissociation at a more implicit level. Similar considerations could be extended for the assessment of emotion regulation. Particularly, results from self-report measure should be replicated using adequate clinical interviews (Ng et al., 2017; Werner et al., 2011). Furthermore, referring to the implicit effects of dissociation on different emotion regulation strategies, empirical research should focus on the impact of dissociative mechanisms on behavioral and cognitive performance linked to specific emotion regulation strategies (e.g., Gyurak et al., 2009; Lantrip et al., 2016).

5. Conclusion

Despite limitations discussed above, this is the first meta-analysis that systematically summarize the relation between dissociation and emotion regulation. Our findings suggest a provisional model clarifying the relationship between dissociation and emotion regulation.

Particularly, dissociative phenomena might reflect automatic and non-voluntary mechanisms that arise in order to manage emotional reactions in response to emotional-eliciting stimuli (i.e., external and internal) and affect each stage of emotion generation. Specifically, dissociation might interfere with adaptive functioning of attentional processes, cognitive appraisal and response modulation mechanisms involved in emotion regulation. Referring to significant associations with disengagement and aversive cognitive perseveration domains, dissociation could have two main functions within emotional functioning, namely non-deliberate avoidance and over-control of emotionally relevant situations and related reactions. These non-voluntary mechanisms cause problematic effects on emotional functioning and adaption through: a) the reinforcement of inability to process emotional information, especially negative one (e.g., Frewen and Lanius, 2006a); b) interferences on emotional learning (e.g., Ebner-Priemer et al., 2009); c) fragmented and rigid threat appraisals of a wide range of emotional-eliciting situations (e.g., Morgan et al., 2001); d) alterations of emotional feeling (e.g., numbing Frewen and Lanius, 2006b). The reciprocal relationships between dissociation and maladaptive emotional regulation strategies are particularly expressed across different clinical conditions. Accordingly, dissociation phenomena and their functions should be systematically assessed within the clinical practice considering their well-documented detrimental effects on the effectiveness of several treatment approaches for different clinical conditions (e.g., Bae et al., 2016; Kleindienst et al., 2011; Semiz et al., 2014). Considering the impact of dissociation in reinforcing maladaptive modalities of emotion regulation, it should be considered one of the primary treatment targets independently of theoretical orientation of intervention and clinical conditions. Nevertheless, the significant relationships between dissociation and emotion regulation are also confirmed among nonclinical samples. In conclusion and consistently with these results, dissociation in the context of emotion regulation should be considered as a basic neuro-mental mechanism that automatically contributes to the over-modulation emotional states through avoidance reactions from internal and external reality at the cost of adaptive regulation strategies.

Authors contributions

AS and MC designed the theoretical framework and the logic of the study. MC analysed the data and together with AS wrote a first draft of the manuscript that was critically revised by GN. All authors approved the final version of the manuscript.

Declaration of competing interest

Acknowledgments

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