Mapping correlates of adolescent emotion dysregulation: A text-mining based systematic review

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Author note

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Abstract

Adolesence is a developmentally sensititve period for emotion dysregulation. Although substantial empirical research has addressed relevant risk factors, the literature is fragmented across subdisciplines, and an integrating framework is lacking. This systematic review of 6305 papers used text mining to map correlates of adolescents’ (ages 10-25) emotion dysregulation. First, we established a baseline of relevant terms gleaned from theory and recent narrative reviews. Then, we conducted two text mining analyses to examine term/document frequency and co-occurrence in author-provided keywords and abstracts. Results reﬂected constructs commonly featured in theory and narrative reviews, but also identified underrepresented themes. This research constitutes a first step towards integrating the literature, and illustrates how text mining reviews may complement narrative reviews.

*Word count:* 6311

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A key developmental challenge in adolescence is acquiring mature emotion regulation skills (Crone & Dahl, 2012; Zimmermann & Iwanski, 2014). Emotion regulation is integral to mental health (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Braet et al., 2014; Schäfer, Naumann, Holmes, Tuschen-Caffier, & Samson, 2017) and social functioning (Reindl, Gniewosz, & Reinders, 2016). For as many as one in five individuals, adolescence marks the onset of emotion regulation-related mental illness, which can persist throughout the life course (see Lee et al., 2014). It is therefore crucial to identify which risk factors and environmental hazards render some adolescents more susceptible to emotional difficulties than others. Although there is an abundance of empirical work on adolescents’ emotion regulation, the literature is somewhat fragmented, because the topic has been investigated from different (sub)disciplines. As a result, there is a lack of unifying theory, and intrinsic limitations of narrative reviews prohibit comprehensive coverage of the vast but diffuse literature (Buss, Cole, & Zhou, 2019).

The present systematic review seeks to overcome these limitations by adopting a novel method: the text mining based systematic review. We set out to map the constructs associated with adolescent emotion regulation based on a systematic review of the empirical literature. Traditional narrative literature reviews have been shown to be marred by reliance on small convenience samples of the literature, confirmation bias, and an undue emphasis on positive results (Littell, 2008). Text mining, by contrast, is uniquely suited to provide a comprehensive overview of the literature. It can cover vastly greater corpora than a human reader, and the process by which text mining gleans insights from the literature is more objective, transparant, and reproducible. Where human readers might be inclined to structure their reading of the literature around established ideas, the inherent “fairness” of text mining gives emerging themes in the literature a chance to come to the fore. Text mining identifies important topics in a body of literature and reveals which constructs are often studied together. This potentially reveals topics and connections missed by narrative reviewers, thereby laying the groundwork for future empirical and theoretical work.

## Why adolescence is an important life stage for emotion regulation

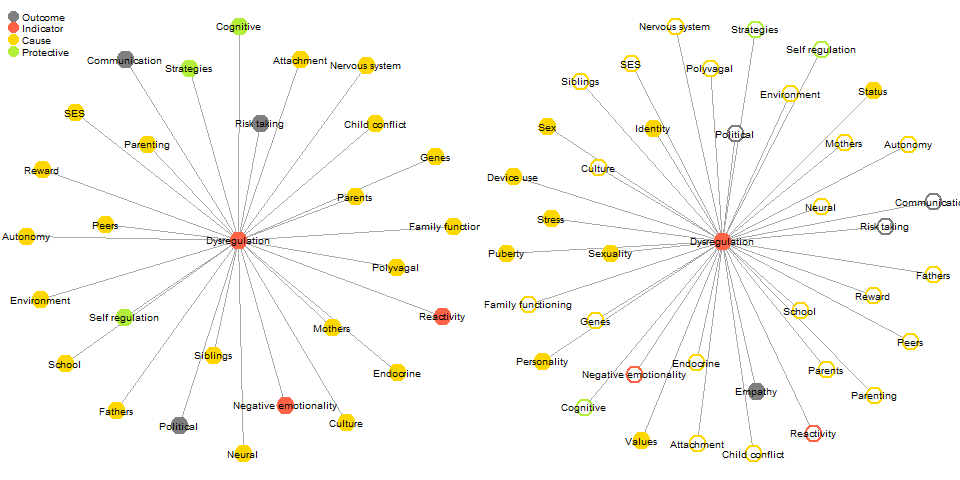
Adolescence is defined as a life stage ranging from pubertal onset to adult-like independence (Steinberg, 2014). It is thus demarcated by both biological and socio-cultural factors. It has been argued that, due to accellerated pubertal onset and delayed transitions to adult roles, adolescence now ranges from 10-24 years in the modern Western world (Sawyer, Azzopardi, Wickremarathne, & Patton, 2018). Adolescence is increasingly seen as a developmentally sensitive period for mature emotion regulation skills. During this period, children experience rapid biological, cognitive, and social changes that prompt new emotional experiences, and tax existing regulatory abilities (Steinberg, 2014). At the same time, the staggered development of motivational-emotional and regulatory brain circuits gives rise to a maturity gap (Crone & Dahl, 2012). This leads youngsters to pursue new experiences in life and love, without being fully prepared to cope with the emotional outcomes. Due to these coalescing changes, adolescents display a restricted repertoire of emotion regulation strategies compared to younger or older individuals (Zimmermann & Iwanski, 2014). Consequently, adolescents experience more frequent and intense (negative) emotions than children or adults (see Silk, Steinberg, & Morris, 2003). The literature thus paints a picture of adolescence as a chrysalis for emotional development: Children enter this stage with emotion regulation skills adapted to the challenges of childhood. During adolescence, emotional systems are rearranged substantially. These changes render adolescents temporarily vulnerable to emotional dysregulation, but ultimately serve a functional role in acquiring mature emotion regulation skills. Eventually, most adolescents emerge ready to take on the challenges of early adulthood. Unfortunately, a sizeable proportion of adolescents instead manifests enduring emotional difficulties (Lee et al., 2014).

## The consequences of difficulties in emotion regulation

The consequences of difficulties in emotion regulation are extensive, well-documented, and persist throughout the life course. Meta-analyses indicate that such difficulties are associated with internalizing, and to a lesser extent, externalizing, psychopathology (Aldao et al., 2010; Schäfer et al., 2017). Individuals who engage in maladaptive emotion regulation strategies also experience more negative emotions, diminished well-being, and greater strain in interpersonal relationships (Bell & Calkins, 2000; Gross & John, 2003). Given the prevalence of emotional difficulties and their implications for individual mental health, wellbeing, and social functioning, and their downstream cost to society as a whole (Lee et al., 2014), it is essential to have a solid understanding of the risk factors associated with adolescents’ emotion regulation difficulties.

## Existing theoretical landscape

The results of our text mining analysis of the empirical literature are best understood against a backdrop of the existing theoretical landscape. We therefore provide a summary theoretical review. Other recent publications offer more detailed reviews of theories of emotional development (Buss et al., 2019) and emotion regulation in adolescence (Riediger & Klipker, 2014). The correlates of emotion regulation difficulties discussed in the theoretical review below are visually summarized in the left panel of Figure 1[[1]](#footnote-24).



*Figure* *1:*. Correlates of emotion regulation difficulties according to theory (left panel) and narrative reviews (right panel). Transparent circles indicate constructs also represented in the theory.

Among the oldest relevant theories of adolescents’ emotional development is Hall’s notion of “storm and stress” (see Arnett, 1999). It describes how hormonal changes diminish self-control and increase reactivity, leading to difficulties in emotion regulation, conflict with parents, and risky behavior. In modern theories, this notion of diminished self-control and increased emotional reactivity has been retained - although it is now considered to be a normative change that facilitates emotional maturation (Crone & Dahl, 2012), at the risk of emotional disturbance (Arnett, 1999; Lee et al., 2014).

One example of a normative theory of emotional development in early childhood is presented by Sroufe (1995). Sroufe argues that, as children grow older, their increasing self-regulatory abilities drive a transition from external emotion regulation by primary caregivers towards autonomous emotion regulation. This theory focuses on two drivers of development: social and cognitive influences. Social influences mainly occur through parental co-regulation, parenting behaviors, and parent-child attachment. Cognitive influences occur through the development of the central nervous system (CNS), cognition, and self-regulation.

This emphasis on social influences and neurocognitive development is reflected in many theories. Some of these focus primarily on neurocognitive development. For example, polyvagal theory closely links emotional experience - and regulation - to autonomous nervous system functioning (Porges, 1995). A more recent neurocognitive theory relevant to adolescents’ emotion regulation development is Crone and Dahl’s model of social-affective engagement and goal flexibility (Crone & Dahl, 2012). Like other authors (e.g., Casey, Jones, & Somerville, 2011; Cracco, Goossens, & Braet, 2017), Crone and Dahl argue that the developmental asymmetry between motivational and inhibitory brain circuits gives rise to a “maturity gap” in middle adolescence. What distinguishes Crone and Dahl from related writings is the greater attention to adolescents’ diverging destinies: the question why some youngsters flourish while others languish. They argue that adolescents’ cognitive engagement is dynamically responsive to social and motivational goal salience. This flexibility, on the one hand, prepares adolescents to effectively engage cognitive systems in novel challenging situations in a way that facilitates developing mature regulatory abilities. On the other hand, it places them at risk to act impulsively in pursuit of peer approval. In terms of explanans, this theory focuses primarily on cognitive factors and the role of peers, with less attention to factors such as parenting. Although this theory focuses on adolescence specifically, an important limitation is that it only tangentially relates to emotion regulation.

Other theories emphasize socialization to a greater extent. One such theory is Morris’ tripartite model, which focuses specifically on parents’ role in emotion regulation development (2007). It describes three pathways through which parents shape emotion regulation development: Through observation and modeling, parenting practices, and the emotional family climate, which in turn involves attachment and marital relationship quality. Morris and colleagues emphasize the relevance of mothers, fathers, and siblings. Others have adapted the tripartite model to describe the role of peers in adolescents’ emotion regulation development (Reindl et al., 2016). A more abstract take on socialization is found in Holodynski and Friedlmeier (2006)’s internalization model of emotional development. Unique aspects emphasized in this theory are the interplay between emotion and communication, and the internalization of the cultural symbolic function of emotion. These theories explain the process of socialization in great detail, but one potential limitation is that they are not embedded in a larger unifying framework.

Looking beyond the developmental literature, theories of the phenomenon of emotion regulation offer additional insight into intra-individual drivers of emotion regulation development. Perhaps the most influential theory is Gross’ (2013) process model, which describes the process of emotion regulation from eliciting cue to ultimate response. According to Gross, individuals use strategies to modulate the different stages of this process, consciously or otherwise. Culture plays a role too, as the effectiveness, desireability, and consequences of different strategies depend on the social context (see Bariola, Gullone, & Hughes, 2011). Similar to Gross’ theory, the social information processing theory of emotion also describe the role of cognitive processes and strategies in emotion experience and regulation (Lemerise & Arsenio, 2000).

Finally, given our interest in risk factors that render adolescents susceptible to emotional difficulties, we should mention two theories widely invoked to frame research on developmental influences: Bronfenbrenner’s bioecological model, and Sameroff’s transactional model. Bronfenbrenner’s model (Bronfenbrenner & Morris, 2007) describes how the environment shapes individual development. Each individual is imbued with certain biological predispositions, and develops over time, in interaction with contextual influences. These influences range from the microsystem, composed of those people close to the individual, to the macrosystem, consisting of indirect political and economic influences, to the exosystem, consisting of cultural norms and values. Sameroff’s model is somewhat compatible with the bioecological model (Sameroff, n.d.), but focuses more on the interplay between nature and nurture. It conceptualizes development as a product of reciprocal influences between the child and the environment. Sameroff distinguishes between proximal influences, for instance, through parents (the microsystem in Bronfenbrenner’s model), and distal influences; structural factors indirectly shaping development, like socio-economic status, schools, and the community (macro- and exosystem). With increasing age, distal influences gradually gain ground on proximal influences. These theories are broad enough to contextualize any developmental study, but lack specificity, which curtails their utility in generating hypotheses.

### Shortcomings of existing theory.

Despite the abundance of theory *relevant* to emotion regulation in adolescence, the theoretical literature has several limitations. First, few theories have explicitly addressed the life stage of adolescence. This life stage differs qualitatively from infancy, childhood, and adulthood (Bariola et al., 2011). It is therefore questionable whether more general theories, or those focused on different age groups, can be generalized to adolescents. Furthermore, few theories have comprehensively addressed important predictors of development in this life stage, and none directly guide contemporary research in the field (see Buss et al., 2019; Riediger & Klipker, 2014). Finally, available theories vary widely in scope: Some are broad but somewhat non-specific, and others describe a specific phenomenon in detail, but lack a broader perspective. It would be beneficial to bridge these levels of analysis. In sum, there is a need for more integrative theory formation, in order to provide a unified framework that could guide future empirical work. The present study lays the groundwork for such theory development, by providing a text-mining based inductive systematic review of the field.

## Prior narrative reviews

Whereas theory provides a top-down frame of reference for understanding a phenomenon, literature reviews can provide a bottom-up, inductive understanding. Given the noted absence of a single overarching theory, reviews might provide additional insight into factors considered relevant in the etiology of adolescents’ emotion regulation competencies. Innovative text mining methods are promising in this respect, because they can comprehensively review the available literature. Narrative reviews, however, constitute the status quo. We will therefore examine how two excellent narrative reviews on emotion regulation in adolescence complement the aforementioned theoretical literature (Bariola et al., 2011; Coe-Odess, Narr, & Allen, 2019). The right panel of Figure 1 visually distinguishes constructs uniquely covered by these narrative reviews, relative to the issues also addressed in the theoretical literature (left panel).

The seminal review by Bariola et al. (2011) addresses individual psychological factors such as temperament, and biological factors like neurocognitive development and genetic predispositions. Furthermore, the authors address proximal social influences, including parents, teachers, and peers, and specific mechanisms through which these individuals exert their influence, including parenting and modeling. Finally, they address distal factors, including the role of culture and the media. Barriola and colleagues also call for future research to address parents’ role beyond early childhood. They further argued that the role of fathers in emotion socialization warrants further scrutiny - a topic that is now receiving more attention (e.g., see Van Lissa, Keizer, Van Lier, Meeus, & Branje, 2019; Van Lissa & Keizer, 2020).

A more recent review by Coe-Odess et al. (2019) offers a nuanced discussion of several issues that complement prior publications in this field. For instance, the authors cover the implications of physiological changes in detail, including neurocognitive development and pubertal maturation. As adolescents become increasingly individuated, conflict with parents peaks. This conflict, in turn, impacts emotion regulation, both in terms of day-to-day mood variability and dispositional emotion dysregulation (see also Van Lissa, Hawk, Koot, Branje, & Meeus, 2017). Compared to children, adolescents also become increasingly oriented towards peers. This includes increased sensitivity to social status and norms, along with the associated increase in peer pressure and risk taking. Pubertal development also initiates the emergence of sexual and romantic behavior, and the intensification of both biological sex differences and gender stereotyped behavior. With regard to the process of emotion regulation, Coe-Odess and colleagues discuss the importance of strategies, and point out that, in addition to negative emotionality, positive emotionality also peaks in adolescence. Relatedly, the authors describe how hormonal changes precipitate an increased stress response, which might help explain adolescents’ greater susceptibility to emotion dysregulation. Finally, going beyond the implications of cognitive development discussed in other publications, the authors discuss how an greater capacity for abstract thought relates to identity formation - a key challenge in adolescence (Meeus, 2011) - and to increased emotional understanding, and by extension, empathy (see also Van Lissa et al., 2014).

As can be seen in Figure 1, there are notable parallels between the relevant factors highlighted by these narrative reviews, and the aforementioned theoretical literature. Nevertheless, these literature reviews also touch upon issues that have received little attention in theoretical work. These include specific individual differences at the biological and psychological level, including genetic predisposition, hormones, pubertal onset, gender, sexuality, temperament, identity, empathy, and stress. Further introduced are proximal influences, including the role of media, norms, and social status. This illustrates that reviews of the empirical literature can contribute additional insight into key factors in adolescents’ emotion regulation development. However, an important remaining limitation is that all reviews in this field have been unstructured narrative reviews, which are known to be limited in scope and biased (Littell, 2008). We seek to complement preceding work by using text mining to conduct a more comprehensive empirical literature review, and map the factors associated with adolescent emotion regulation.

## The present paper

The present paper aims to map the constructs related to adolescent emotion dysregulation, based on a systematic review of the literature. First, we conducted a systematic search to elicit a corpus of relevant literature. Second, we used text mining techniques to extract relevant constructs from the corpus. Third, we used a dictionary to pare down the extracted constructs to meaningful superordinate categories. Fourth, we mapped interrelations between these constructs. Fifth, we classified contstructs as potential predictors or outcomes. .

# Methods

## Search strategy

All searches were conducted on Web of Science, the most comprehensive database for which we had permissions for exporting keywords and abstracts. The search strategy was based on procedures described by Staaks (Staaks, n.d.). First, we manually constructed a reference set of 15 articles. Then we constructed a search string to retrieve these articles from Web of Science. The search was overly inclusive, returning 29 records. As these were all highly relevant, we updated the reference set to include all 29 results. Next, we tested our search string, which consisted of synonyms of emotion regulation and adolescence:

TS=("emotio\* regulation" OR "anger regulation" OR "sadness regulation" OR  
"emotion\* competence" OR "emotion\* adjustment" OR "emotio\* dysregulation" OR  
"anger dysregulation" OR "sadness dysregulation" OR "emotio\* problem\*" OR  
"emotion\* maladjustment") AND TS=(adolescent\* OR teen\* OR pubert\* OR youth)

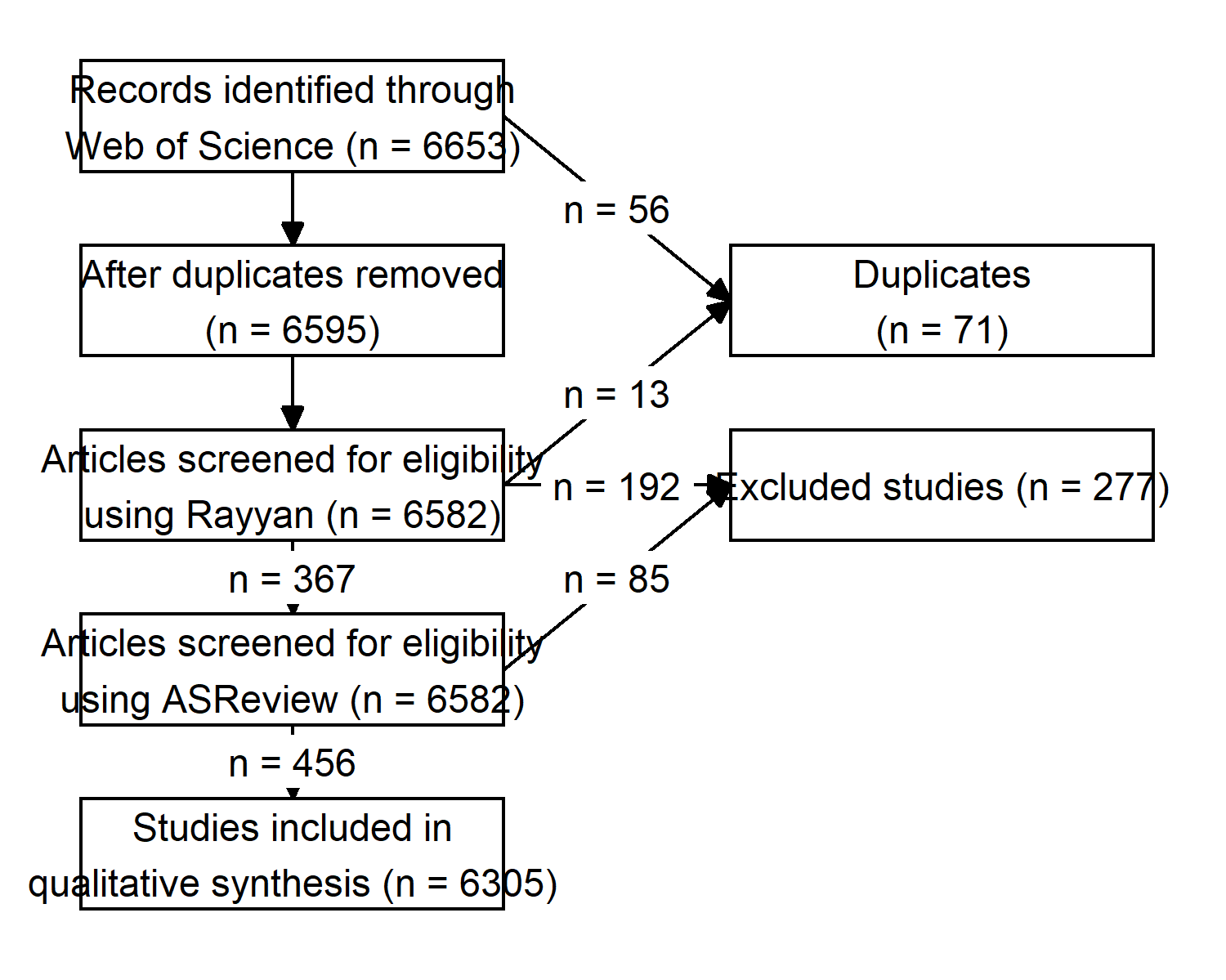
This string returned 6653 results, and matched 25 of the 29 records in the reference set. To match all 29 reference set items, three additional terms would have to be added to the search string. Adding the terms "emotio\* socialization" OR "emotio\* processes", as synonyms for emotion regulation, would result in 191 more hits, most of which did not meet the inclusion criteria used for screening, as explained below. Adding the term "development\*", as synonym of adolescence, added 3628 new hits, many of which were not focused on adolescence. We thus deemed these terms to be overly inclusive, and proceeded with the original search string above.

## Deduplication

Duplicates were identified based on exact DOI matches (2 duplicates), and title similarity (54 duplicates). Manual screening in Rayyan resulted in the removal of an additional 13 duplicates.

## Screening

Papers were screened based on two main criteria: First, papers had to address emotion regulation or a synonymous construct. Second, the target population must overlap with the life stage of adolescence, defined as the age range from 10-24. Thus, for example, an article reviewing the role of hormonal changes in emotional adjustment throughout the entire life course, including adolescence, would be deemed relevant. Preliminary screening was conducted in Rayyan QRCI (Ouzzani, Hammady, Fedorowicz, & Elmagarmid, 2016). Papers were sorted using Rayyan’s ranking algorithm. To train the algorithm on exclusion criteria, screening focused on abstracts most likely to be excluded. After coding 559 papers, screening continued in ASReview - a free, open source alternative to Rayyan QRCI (Van de Schoot et al., 2020). This program uses active learning to build a customizable machine learning model for article inclusion. We used a naive Bayes model, and focused on exclusion of irrelevant papers. In ASReview, an additional 541 papers were screened. Screening again focused on articles most likely to be excluded, and continued until, among the most recently screened 100 papers, only 6 were excluded. The screening procedure is detailed in Figure 2. In total, 6305 papers were retained for analysis.



*Figure* *2:*. Record screening flowchart

# Analysis 1: Author keyword mapping

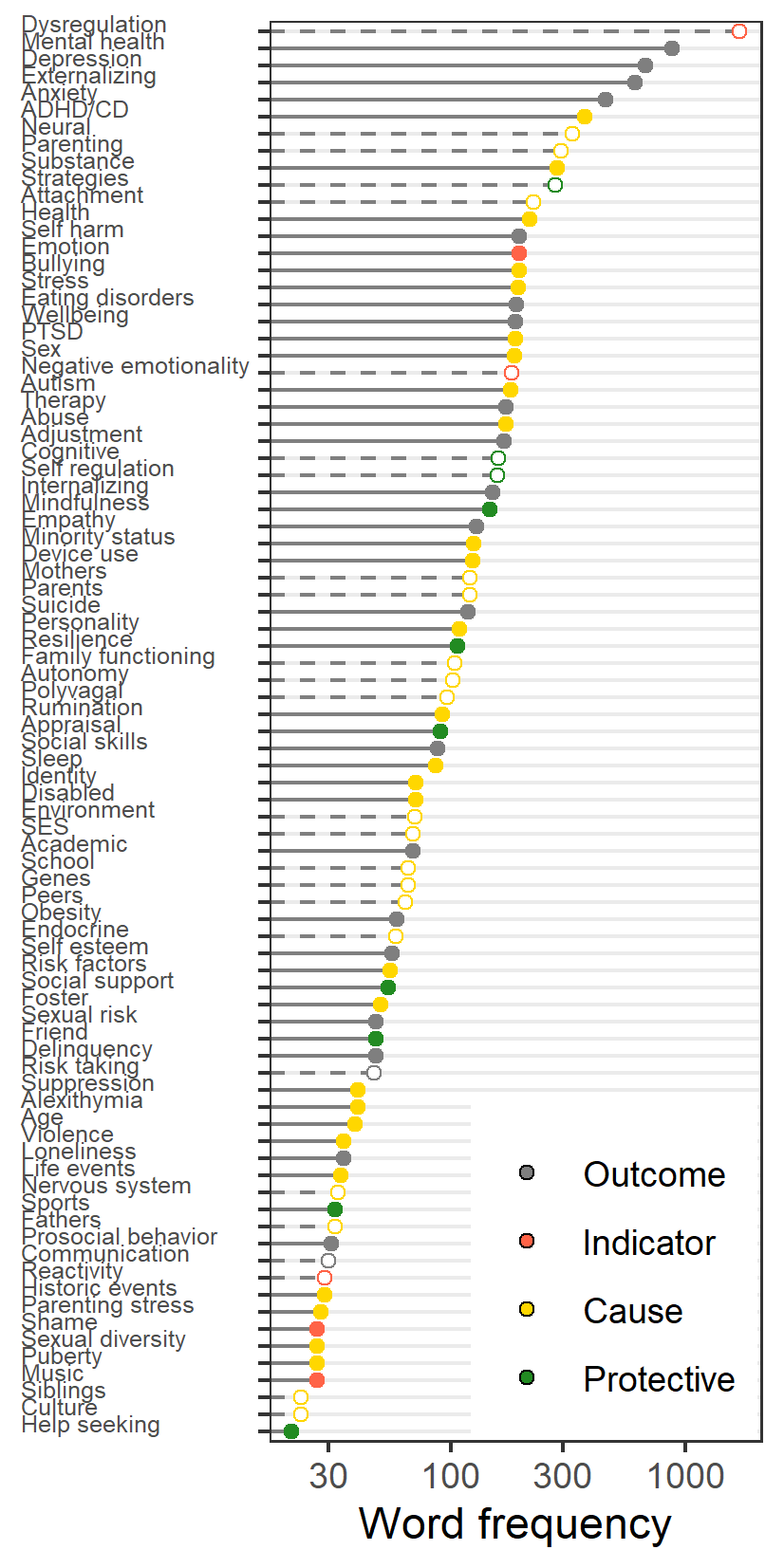
The corpus for this first analysis consisted of the author-provided keywords for the selected articles. We extracted keywords by document, and used a dictionary created specifically for this study to classify related terms. The dictionary describes 109 terms using 462 regular expression queries. The author composed a first draft of the dictionary. This draft was subsequently updated in two ways: First, key terms from the literature were added to the dictionary while writing the Introduction. Second, all frequently occurring uncategorized words were added to the dictionary, until none remained. An exclusion list of methodological terms and other non-substantive words was generated using the same procedure. After applying the dictionary and exclusion filter, and removing records with no (remaining) keywords, the resulting corpus consisted of 5031 documents with 8080 unique terms.

## Structural topic modeling

One important step before reviewing the literature is to examine heterogeneity in the corpus of collected texts. For example, it would be useful to know whether there is a clear divide between psychiatric and developmental texts. To empirically test for heterogeneity, we conducted topic modeling using latent dirichlet allocation (Blei, Ng, & Jordan, 2003). This is a clustering method suitable to high-dimensional sparse feature matrices. In this case, the features are author keywords. We used the term frequency/inverse document frequency (TF-IDF) to select terms used frequently in a document, but not used frequently in the corpus, which could therefore be more diagnostic of subgroup membership. Selection terms with an TF-IDF greater than the median resulted in a corpus of 2302 documents and 3118 terms. We considered a range from 2-20 topics, evaluating fit based on the BIC, and interpretability based on the entropy of the posterior document/topic probabilities. The BICs followed a near-perfect linearly increasing trend, indicating that no subcorpora could be identified. Congruently, all entropies were near-zero, which means that the posterior document/topic probabilities were effectively uniformly distributed. Thus, no subcorpora could be identified, and we proceed with an analysis of the whole sample.

## Identifying common terms

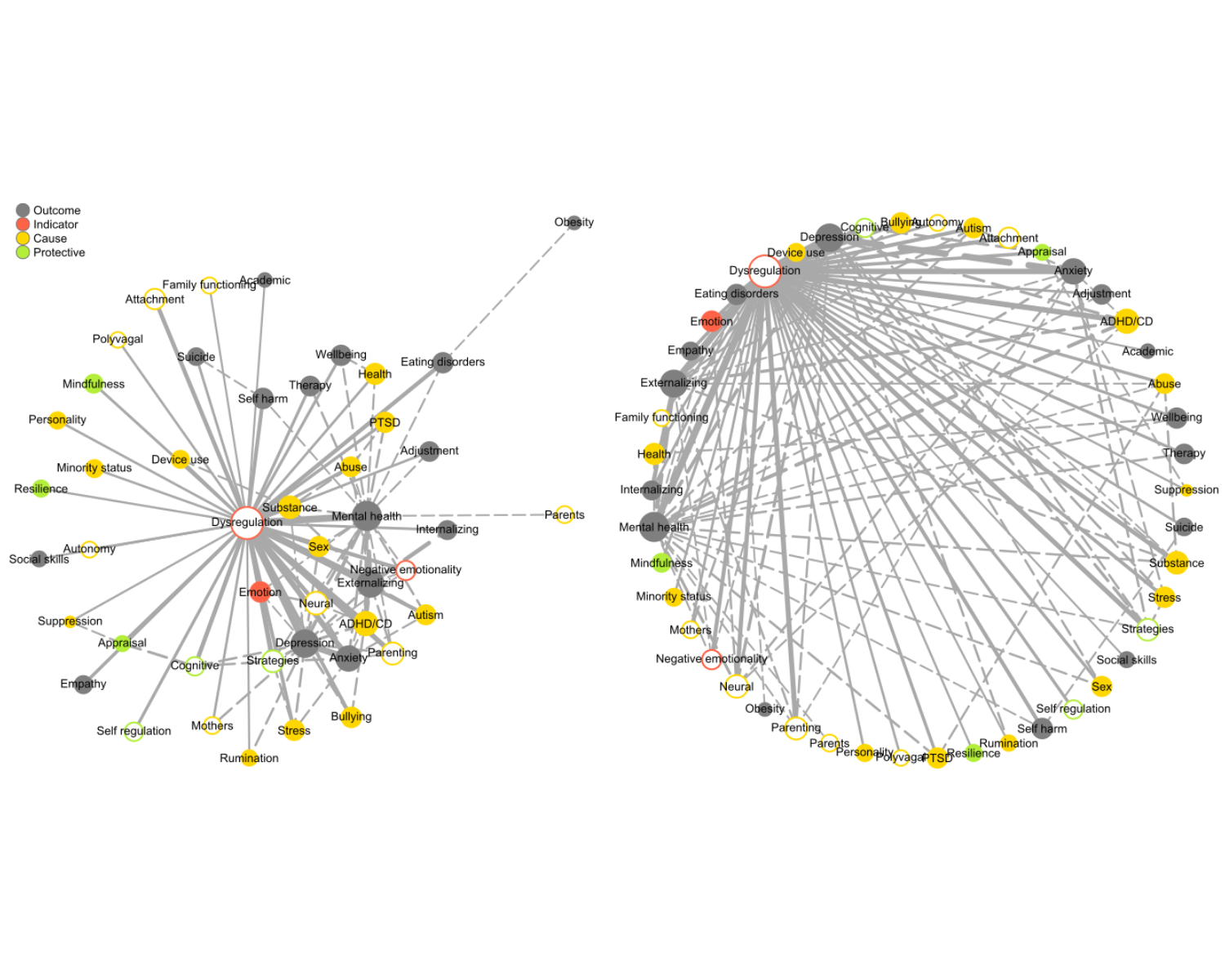
To identify what issues are covered in this corpus, we examined the terms occurring in the largest number of texts. We modeled word frequency using a negative binomial distribution, and retained those exceeding the percentile. This resulted in 83 terms, which occurred in 4826 documents. To illustrate what issues are covered in this body of literature, the selected terms are displayed in Figure 3, on a logarithmic scale to reduce the skew of the negative binomial distribution.



*Figure* *3:*. Document frequency of terms selected for Study 1. Dashed lines and transparent circles indicate constructs also represented in the theory (cf Figure 1).

## Mapping the literature

Based on our theoretical review, each of the selected terms was coded as being either a putative ‘Cause’, ‘Outcome’, ‘Protective factor’, or ‘Indicator’ (a closely related construct) of emotion dysregulation. We stress that this is a subjective and rudimentary classification, intended only to stimulate further reflection on the role of each construct. We acknowledge that many of these associations are likely to be bidirectional (e.g., emotion dysregulation is known to be both a cause and consequence of conflict with parents, Van Lissa et al., 2017). Next, we computed a term co-occurrence matrix, which represents how frequently words occurred within the same document. To aid interpretability, we again pruned small coefficients by modeling co-occurrence using a negative binomial distribution, and retaining co-occurrences exceeding the percentile. Figure 4 displays the term cooccurrence matrix as a force directed graph.



*Figure* *4:*. Force directed graph for Study 1 co-occurrence analysis. Two layouts are presented to aid interpretation. Size of nodes and edges represents word/co-occurrence frequency. Dashed lines represent links not involving dysregulation. Transparent circles indicate constructs also represented in the theory (cf Figure 1).

## Results

Based on term document frequency (Figure 3), it is clear that emotion dysregulation and its mental health-related outcomes are foremost among the common terms in the corpus. Other frequent terms reflect important themes discussed in the theoretical review of the literature; for instance, the terms *neural*, *parenting*, and *stress* correspond to themes discussed by Coe-Odess et al. (2019): Neurocognitive development, the role of the parents, and adolescents’ increased stress response. Importantly, the most common terms also include several concepts not featured prominently in the theoretical review. For example, *ADHD/CD* (cf. Braet et al., 2014), *substance* use (cf. Coe-Odess et al., 2019; Pierrehumbert et al., 2002), and *minority status* (cf. Myers, 2009, 2009) are common in the corpus, but featured less prominently in the theoretical review.

Based on the co-occurrence graph (Figure 4), it is evident that emotion dysregulation is a central construct, and that most of the other constructs are linked directly to emotion dysregulation, which suggests that our search was successful in identifying factors considered to be relevant for adolescents’ emotion dysregulation. Otherwise, the graph is relatively sparse, with few interconnections between terms.

## Discussion

This first analysis used author keywords to map common topics in the literature pertaining to adolescents’ emotion dysregulation. The results reflected some of the constructs commonly accepted as relevant in theoretical literature and empirical reviews - particularly those pertaining to neurodevelopment and socialization. The most frequently occurring words were classified as potential outcomes of emotion regulation difficulties, and revealed a theme related to mental health. This validates the notion that adolescent emotion regulation is implicated in a range of mental health problems, which underlines the importance of this area of research.

In addition to the themes addressed in the theoretical introduction, several novel themes emerge from the terms newly identified in this analysis. Developmental disorders constitute such a theme, as ADHD/CD and autism are ranked highly. Another theme is the role of physical health (sic), also reflected in terms like sleep, sports, and disability status. External stressors are another important theme, reflected in bullying, stress, PTSD, abuse, violence, life events, historic events (e.g., earthquakes, war), and parenting stress. Structural disadvantage is certainly a factor overlooked in existing theory, and is reflected in minority status, disability status, socio-economic status, adoption status, sexual diversity, and the adorementioned developmental disorders, as neuroatypical individuals may also experience such disadvantage. These insights illustrate how inductive reviews may complement existing theory and narrative reviews, and can reveal blindspots.

In terms of the co-occurrence network, connections among topics were notably sparse. Many constructs were only related to emotion regulation, and there were relatively few interconnections between elements. This observation substantiates the prior claim that this literature is somewhat fragmented (Buss et al., 2019). This sparse property of the network explains, in part, why some of the most prevalent terms based on term document frequency (see Figure 3) are absent from the co-occurrence graph. These terms were not strongly related to any other terms in the main network. Amongst the terms culled from the co-occurrence graph are the potential causes *Sleep*, *Disabled*, *Identity*, *SES*, *Peers*, *School*, *Endocrine*, *Risk factors*, *Foster*, *Genes*, *Alexithymia*, *Age*, *Violence*, *Life events*, *Nervous system*, *Fathers*, *Environment*, *Historic events*, *Parenting stress*, *Puberty*, *Sexual diversity*, *Siblings*, and *Culture*, the potential outcomes *Self esteem*, *Delinquency*, *Sexual risk*, *Risk taking*, *Loneliness*, *Prosocial behavior*, and *Communication*, and the potential protective factors *Social support*, *Friend*, *Sports*, and *Help seeking*.

Many of these excluded constructs represent active ongoing areas of research, including research on *fathers* (Van Lissa et al., 2019), *identity* (Campbell, Zimmer-Gembeck, & Duffy, 2019), *friendship* and *social support* (Y. Wang et al., 2020), *autonomy* (Brenning, Soenens, Petegem, & Vansteenkiste, 2015; Vrolijk, Van Lissa, Branje, Meeus, & Keizer, 2020), *sexual risk* (Brown et al., 2006), and *loneliness* (Spithoven, Bijttebier, & Goossens, 2017). The fact that these constructs are absent from the graph does not suggest that they are unimportant. Rather, it indicates that they are not yet well-integrated in the broader literature on adolescents’ emotion regulation, and are therefore prime candidates for future research.

# Analysis 2: Abstract text mining

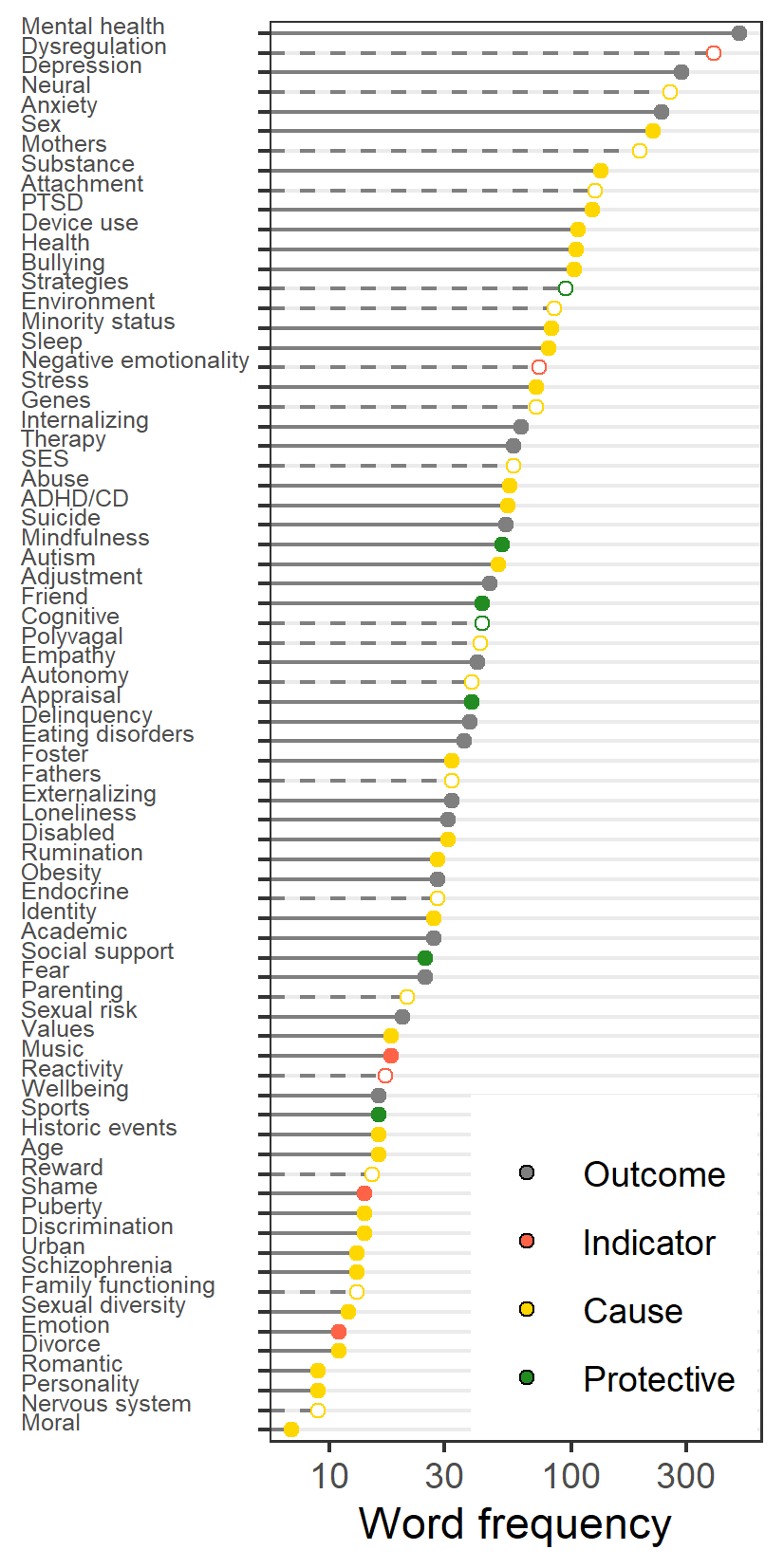
The corpus for this second analysis consisted of the abstracts of the selected articles. Keywords, as examined in Analysis 1, convey high-quality information because they are carefully chosen by authors to capture the essence of a study. However, as authors are typically limited to 5 keywords, some nuance may be lost. Abstracts, by contrast, offer greater freedom of expression, but present a greater challenge when it comes to extracting relevant information. To perform feature extraction, we first applied the natural language processing technique “part-of-speech tagging” (POS-tagging), which identifies a word’s grammatical function within the sentence context. Then, we used POS-tagging to retain only nouns and adjectives, which helps derive more interpretable text mining models (Martin & Johnson, 2015). Finally, we used stemming to reduce the retained terms to their root form.

## Structural topic modeling

To assess the homogeneity of the corpus of abstracts, we again conducted topic modeling with features selected based on TF-IDF, following the same procedure as in Analysis 1 (Blei et al., 2003). The dataset consisted of 6076 documents and 7800 terms. As before, the BICs followed a near-perfect linearly increasing trend, and all entropies were near-zero. Thus, no interpretable subcorpora could be identified, and we proceed with an analysis of the whole sample.

## Identifying keywords

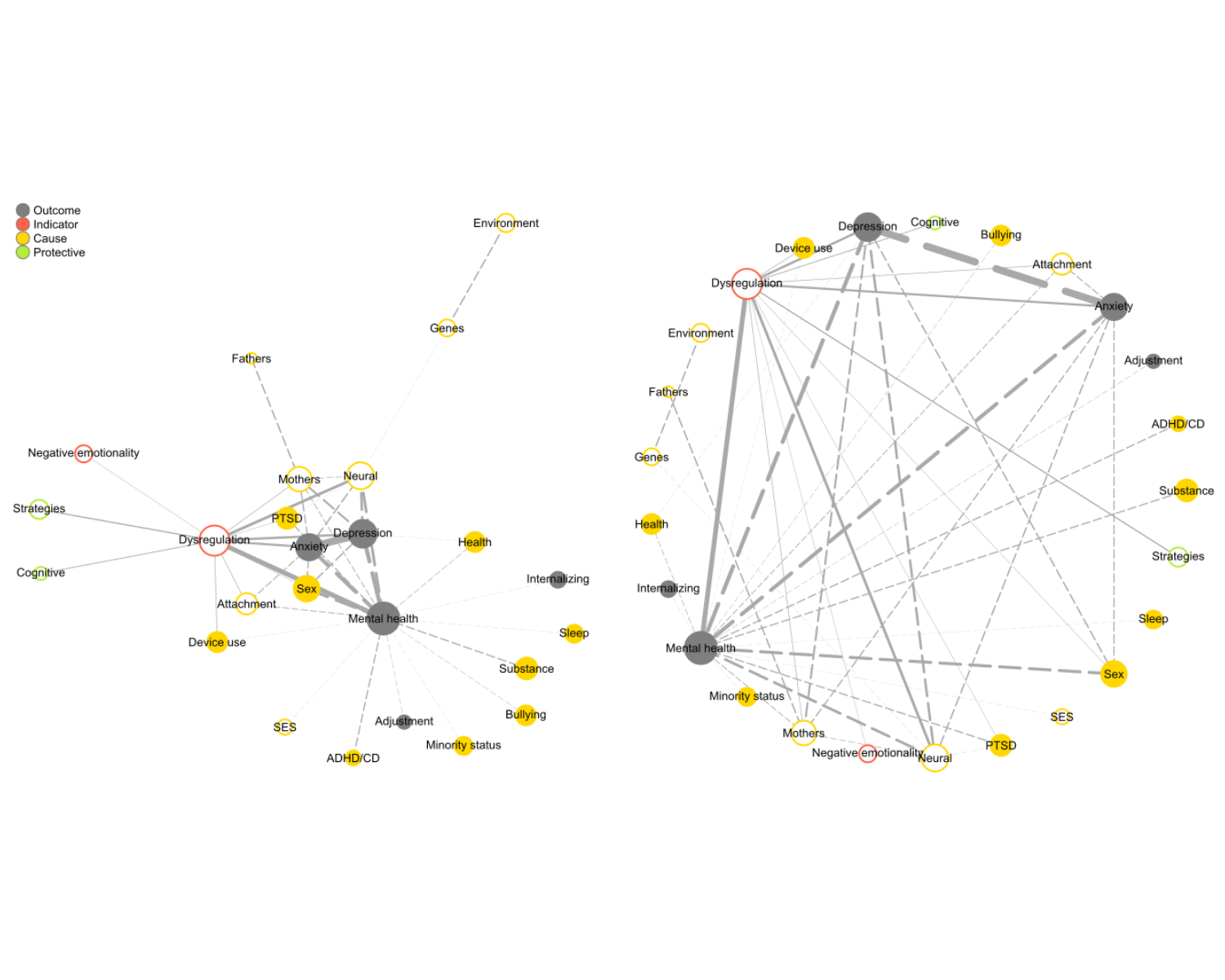
When conducting text mining analysis on unstructured text data (as opposed to author key words), focusing on individual words out of context can reduce interpretability. For instance, our core construct “emotion dysregulation” is already a bigram. To identify more meaningful units of analysis, we applied the textrank algorithm (Wijffels, 2019), an extention of Google’s PageRank (U.S. patent No. 7058628B1, 2006), to identify relevant -grams (with ). The resulting -grams were merged with the original data. After applying the dictionary and exclusion filter as explained in Analysis 1, the resulting corpus consisted of 5097 documents with 11435 unique words. Terms exceeding the percentile of a negative binomial distribution were retained for analysis. The identified important keywords are displayed in Figure 5.



*Figure* *5:*. Document frequency of terms selected for Study 2. Dashed lines and transparent circles indicate constructs also represented in the theory (cf Figure 1).

## Mapping the literature

A term co-occurrence matrix was constructed following the procedure described in Analysis 1. Figure 6 displays the resulting matrix as a force directed graph.



*Figure* *6:*. Force directed graph for Study 2 co-occurrence analysis. Two layouts are presented to aid interpretation. Size of nodes and edges represents word/co-occurrence frequency. Dashed lines represent links not involving dysregulation. Transparent circles indicate constructs also represented in the theory (cf Figure 1).

## Results

Based on term document frequency, it is clear that emotion dysregulation and its mental health-related outcomes are among the most common terms in the corpus of abstracts. The term *neural* again occurred frequently, but other top terms were somewhat less predictable than those emerging in Analysis 1. The term *sex* was more frequent than in Analysis 1, suggesting sex differences are regularly reported in Abstracts, even if they are not a main topic of the study. The term *parenting*, which ranked highly in the preceding keyword Analysis, was displaced by *mothers* amonst the top-ranking terms. This suggests that when the keyword *parenting* is used, the abstract will often reveal that this was operationalized in terms of mothering (as also noted by Pleck, 2004).

There was substantial agreement between the findings of Analysis 1 and 2; of the most frequent terms identified in the author keywords (Analysis 1) were also present in the abstracts (Analysis 2), and conversely, of the most frequent terms from Analysis 2 were present in Analysis 1.

Inspecting the co-occurrence graph for the keyword data, we see a much sparser network than in Analysis 1, with a different structure. We now see that dysregulation and mental health-related terms form a central axis, and that many related terms are connected to this axis, but not always directly to dysregulation. Only the terms *neural*, *mothers*, *attachment* and *ptsd* are connected directly to dysregulation.

Many prevalent terms were entirely absent from the co-occurrence network (Figure 6), as they were not strongly related to any other terms. These terms, which are displayed in Figure 5, include the potential causes *Parenting*, *Stress*, *Autism*, *Abuse*, *Personality*, *Polyvagal*, *Rumination*, *Disabled*, *Identity*, *Endocrine*, *Family functioning*, *Autonomy*, *Foster*, *Age*, *Nervous system*, *Discrimination*, *Historic events*, *Puberty*, *Reward*, *Sexual diversity*, *Divorce*, *Moral*, *Romantic*, *Schizophrenia*, *Urban*, and *Values*, the potential outcomes *Externalizing*, *Eating disorders*, *Wellbeing*, *Therapy*, *Empathy*, *Suicide*, *Academic*, *Obesity*, *Delinquency*, *Sexual risk*, *Loneliness*, and *Fear*, and the potential protective factors *Mindfulness*, *Appraisal*, *Social support*, *Friend*, and *Sports*.

## Discussion

This second analysis focused on the abstracts of the reviewed articles. Several themes emerged from the terms newly identified in this analysis, relative to the theoretical review. These themes bear considerable similarity to the results of Analysis 1. Developmental disorders and physical health are both recurring themes, but are ranked much lower in the present analysis. External stressors are another recurring theme, with indicators including PTSD, bullying, stress, abuse, historic events, and divorce. Finally, structural disadvantage recurs, as reflected in minority status and discrimination, disability status, socio-economic status, adoption status, sexual diversity, and the adorementioned developmental disorders.

A new theme emerging from this analysis is addictive behavior, with highly ranked indicators *substance use* and *device use*. Another new theme pertains to identity and moral development, two topics with a common root in theory (Lapsley, 2015). This theme is also reflected by the terms *values* and *personality*. Finally, sexual development emerges as a theme. Aside from the high-ranking construct (biological) *sex*, this theme is reflected in the terms *puberty*, *sexual diversity*, and *romantic*.

We observed a sparser network, with fewer selected terms. This is likely an artifact of the unstructured nature of abstracts, which introduces greater noise in the analysis. Thus, fewer terms will exceed the detection threshold. Nonetheless, the remaining terms displayed substantial consistency with the analysis of author keywords. This supports the validity of the findings, suggesting that automatic keyword extraction from abstracts can identify relevant constructs, and may constitute a suitable alternative to author-provided keywords.

The emergence of a “central axis” of dysregulation and mental health-related outcomes again suggest that these phenomena are consistently studied together. This makes sense, given the central role of emotion dyregulation in the etiology of diverse mental health problems (Lee et al., 2014). This is in contrast to the lack of interconnectivity among other related constructs, which once more suggests that the literature is somewhat fragmented. This impression is further reinforced by the absence of many frequently occurring terms from the term co-occurrence graph.

# General Discussion

The present study conducted a systematic review of the literature, and performed a text-mining based systematic review to map constructs related to adolescent emotion regulation. The results of this inductive approach echoed many of the constructs considered relevant in the theoretical literature. This suggests that the text mining method can indeed be used to map relevant themes in the literature. Our analysis also revealed several themes that have been underrepresented in theories of adolescent emotion regulation, but nonetheless occur frequently in the empirical literature. These themes include developmental disorders, physical health, external stressors, structural disadvantage, addictive behavior, identity and moral development, and sexual development.

It is important to identify such under-theorized areas of the literature because researchers typically rely on theoretical foundations when planning a study. By providing a conceptual overview of the empirical literature, the present study offers some preliminary guidance regarding potentially relevant topics to consider. An important direction for future research would be to formalize these inductive insights into a new overarching theory of adolescent emotion regulation. In doing so, the co-occurrence graphs of relevant constructs arising from our inductive review may serve as a template for a nomological network: a proto-theoretical diagrammatic representation that describes relationships between constructs relevant to the theory. The generation of such nomological networks constitutes a first step in theory generation (see Alavi, Archibald, McMaster, Lopez, & Cleary, 2018).

Additional insight can be gleaned from the structure of the co-occurrence graphs. First, both analyses revealed close connections between emotion regulation and mental health-related outcomes. This is consistent with the fact that emotion regulation is implicated in the etiology of a range of mental health problems (see Lee et al., 2014). It further emphasizes the societal relevance of this field of research. Both analyses further revealed that most constructs were connected directly with emotion dysregulation or its mental health correlates, with few interconnections amongst constructs. This sparse property of the networks echoes the sentiment by Buss et al. (2019) that the literature is somewhat fragmented. By conducting a comprehensive review using a somewhat objective method (relative to narrative reviews), the present study takes a first step towards integrating this diffuse field. An important future direction for research might be to jointly investigate disconnected constructs, as the lack of connections in the graph indicates a potential knowledge vacuum.

Our work represents one of the first efforts to comprehensively map the literature on adolescents’ emotion dysregulation (cf. Bariola et al., 2011; Coe-Odess et al., 2019). It is also one of the first applications of inductive text mining methods in a systematic review. Text mining reviews offer some potential advantages when compared to narrative literature reviews (Littell, 2008): They can cover vastly greater corpora than a human reader, and follow a somewhat more objective, transparant, and reproducible procedure. As such, text mining reviews offer an interesting perspective that complements theory and narrative reviews.

Of course, the present study also has limitations. One key limitation is that the text mining techniques used here are not able to extract *meaning* from the literature in the way a sentient reader would, an cannot substantively interpret connections between constructs. This limitation is best addressed by considering the output of our text mining analysis as a starting point for further inductive thought or a more in-depth reading of a particular subset of the literature. Throughout this paper, we have offered our interpretation of the results - but we also encourage readers to reflect on the objective results presented here (i.e.: which terms are common, and how these terms are connected), and use these results as impetus for independent inductive reflection, and inspiration for future deductive research. A related limitation is that our methods do not capture the nature of the relationship between co-occurring terms. Instead, we manually classified terms as potential causes, outcomes, protective factors, or indicators based on domain knowledge. Efforts are currently underway to develop unsupervised algorithms capable of distilling causal links from bodies of scientific abstracts (An, Xiao, Yuan, Yang, & Alterovitz, 2019). Future research might substantially advance theory formation by applying such methods to the present corpus.

One final limitation of the present study is that our analysis was limited to keywords and abstracts. Analysis of full-text papers would undoubtedly yield additional insights. Regrettably, paywalls and the lack of a unified API currently prevent such analysis. This highlights the importance of open science: With comprehensive open access publishing, we may one day be able to mine the entire published literature for insights. A proof of concept for this approach was recently provided by the release of 50k+ full-text papers on topics related to COVID-19 for text mining analysis (L. L. Wang et al., 2020).

To conclude, this paper set out to map the factors associated with adolescents’ emotion dysregulation, based on a systematic review of the literature, and text mining analysis of author keywords and abstracts. We provided a map of the literature on adolescents’ emotion dysregulation, covering both familiar ground, and charting unknown territories. Our results suggested that several key themes are currently underrepresented in theory, and that the empirical literature is somewhat fragmented by sub-topic. These inductive insights are relevant for the design of new deductive studies which, even though grounded in theory, might benefit from incorporating additional relevant factors to better elucidate the nature of their association with adolescents’ emotion dysregulation. Our analysis also identified several factors currently on the fringes of the literature, which might represent emerging themes that would benefit from further research (including, for example, the role of fathers Van Lissa & Keizer, 2020). One recommendation for future research might be to study such important but unembedded constructs in conjunction with other more well-established constructs, to bridge gaps in existing knowledge. Several authors have commented on the lack of an overarching theory tailored specifically to adolescent emotion dysregulation. The present work might serve as a starting point for future theory development, with the aim of incorporating themes from the empirical literature within the framework of existing relevant theory.

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1. Based on an author-curated list of keywords, caterogized using the dictionary method introduced in Analysis 1. [↑](#footnote-ref-24)