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The Relation Between Stress and Youth’s Episodic Memory: A Meta-Analysis

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The Relation Between Stress and Youth's Episodic Memory: A Meta-Analysis

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Psychological Science

by

Kirsten Domagalski

Dissertation Committee:
Professor Jodi A. Quas, Chair
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2023

DEDICATION

To

Every woman who walked before me, fighting to make my dreams possible.

And,

To every little girl with big dreams that will follow me. I believe in your resilience and hope to use all that I have learned to create a world where it is less necessary.

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*Healy, J., **Domagalski, K.A,** & Loftus, E.F (2022, March). *Juror verdicts for an alleged sexual assault: Does continued perpetrator-victim contact matter?* [Poster presentation]. American Psychology and Law Society, Denver, CO.

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ABSTRACT OF THE DISSERTATION

The Relation Between Stress and Youth's Episodic Memory: A Meta-Analysis

by

Kirsten Domagalski

Doctor of Philosophy in Social Psychological Science

University of California, Irvine, 2023

Professor Jodi A. Quas, Chair

Researchers interested in youth's abilities to report on stressful and traumatic memories have conducted correlational and experimental studies to investigate the relation between stress and memory throughout childhood and adolescence. This meta-analysis was conducted to integrate findings from these studies and assess the relation between acute stress during an event and subsequent memory of that event in youth ages 3-17. After a comprehensive literature search, 177 correlations were retrieved from 28 independent studies. On average, across studies, stress was not significantly related to memory in youth [r_z= -0.01, 95% PI (-.32, .30), p =0.66]. However, the ways in which stress was measured emerged as a significant moderator of the relation. Pairwise comparisons revealed marginally significant differences between physiological (r_z= 0.06) and self-report (r_z = -0.06) stress categories. Other moderators of stress and memory were also examined, however none of them achieved significance. Residual heterogeneity in the full model and limitations of the meta-analysis are discussed along with key takeaways.

INTRODUCTION

When asked to recount stressful experiences, children's and adolescents' responses often carry significant weight. Most often this weight is recognized in forensic interviews, in which youth who are witnesses, victims, and even perpetrators are questioned about alleged crimes that were often stressful and possibly traumatic (Goodman & Melinder, 2013; Tate, Reppucci, & Mulvey, 1995). However, youth reports are also important in social service settings, where social workers, judicial staff, and service providers need details about youth's distressing experiences to render decisions that ensure youth are protected and safe (Sprague et al., 2018). Moreover, at the US border, a youth's memory of prior traumas may well impact whether they are allowed to enter this country, where they might be sent, and their legal status thereafter (Quas & Lyon, 2019). Even in clinical settings, youth's descriptions of negative experiences are often a focal point of discussion, and help determine the best course of treatment and intervention by professionals who are working to help improve youth functioning (Ollendick, & Cerny, 2013).

Because youth's reports regarding stressful experiences can affect a range of personal, familial, and even societal outcomes, it is not surprising that a sizeable body of research has attempted to document how well youth can recount such experiences (Goodman et al., 1991; Peters, 2018; Peterson & Bell, 1996). Findings, however, have yet to yield a clear and consistent pattern regarding the precise ways that stress affects youth's memory, as reflected in the completeness of the youth's reports but also in the accuracy of the information they provide (e.g., Chen et al., 2000; Peterson, 2010; Quas et al., 2014). That is, findings across studies vary widely. Yet so do the methodological designs, the stressful events themselves that youth are being asked to recall, the ages of the youth in the studies, and even the ways that stress and memory are indexed, both within and across studies (e.g., Baker-Ward et al., 1993; Baugerud, Magnussen &

Melinder, 2014; Burgwyn-Bailes et al., 2001). Given these variations, and the sizeable amount of available literature, it is of enormous value at this juncture to summarize findings from this diverse body of research via meta-analysis.

The current dissertation attempts to do just this. Specific goals were threefold: 1. Evaluate how stress while encoding an episodic experience is related to the completeness and accuracy of youth's memory for that experience, 2. Document developmental variations in the association between stress and youth's episodic memory, specifically by testing age as a moderator; and 3. Examine other methodological and exploratory moderators, including the precise ways stress and memory are operationalized, the type of stressful event for which memory is tested (naturalistic vs. analogue), and the delay between the original episodic event and memory test in order to ascertain whether they account for variations in the association between stress and memory in youth. To address these goals, a comprehensive literature review was conducted to identify investigations of the associations between stress and memory. Then, reports were screened, and data were extracted by a team of doctoral students including the dissertation author. Finally, eligible studies were subjected to a meta-analysis designed to identify in a comprehensive manner how stress is related to youths' memory for stressful prior experiences across studies.

First, before the study is described, definitions of key variables of interest and the scope of the investigation are described. Second, important theoretical models and perspectives concerning stress and memory are reviewed. Because very few of these theories consider youth specifically, the third section turns to the role that developmental processes may play in the relations between stress and memory. Fourth empirical findings from developmental studies of stress and memory are described, distinguishing between naturalistic and analogue studies.

Throughout the review of empirical findings, potential moderators of the associations between stress and memory are identified. Together, these lay the foundation for the study's hypotheses.

Definitions

The terms stress, memory, and youth have unique meanings across contexts and cultures. It imperative to clarify how they are used in the context of the current meta-analysis, which broadly concerns the relations between *acute stress* and *episodic memory* in youth 3-17 years of age.

Acute Stress

The term stress has been used to describe internal feelings and external (i.e., "stressful") events, and has been defined as a reaction to an acutely arousing experience as well as a chronic ongoing condition that stems from long term exposure to adversity (For an overview, see Robinson, 2018). Of interest in the current meta-analysis is *acute stress*, which generally reflects one's reaction to a physical, psychological, or physiological occurrence that momentarily threatens the individual (Rohleder, 2019). This reaction can take on one or multiple forms, including behavioral, physiological, and/or emotional responses. Acute stress is most easily contrasted with chronic stress, which refers to a reaction over time to pervasive, consistent, or repeated threats (e.g., being homelessness, experiencing ongoing neglect, or suffering repeated physical or sexual abuse; Evans & Kim, 2012; Marin et al., 2011). The effects of acute versus chronic stress have different implications for biological and behavioral responses, and lead to very different patterns of changes in neural structures that may underlie and contribute to memory and cognitive functioning (McEwen 2004; Reilly & Gunnar, 2019). Thus, it is not appropriate to consider both forms of stress in a single investigation which focuses on the role that stress during a specific event plays in shaping youth's memory for that event (for a discussion of the potential interactions among different forms of stress and memory, see Goodman, Ogle, & Quas 2010.)

There are several practical and theoretical reasons why the present meta-analysis focused specifically on acute stress responses to either a single or time limited event[1]. In legal contexts, youth are most often questioned about details about incidents of alleged violence (even when violence is repeated, they often need to particularize individual episodes), highlighting the importance of determining how youth's stress levels during a violent incident is related to their memory (Peterson, 2012; Quas, Goodman, & Ghetti, 2000). Likewise, in clinical and other healthcare settings, acutely stressful events may serve as the basis for health-related functioning and need, demanding a clear understanding of the precise ways that stress during those events affect youth's memory (Chen et al., 2000; Peterson & Bell, 1996). Finally, theories on stress and memory are often narrowly concerned with acute stress, given the desire to understand how this is linked to encoding, consolidation, and retrieval of different forms of learning and remembering (Christianson, 1992; Deffenbaucher 1994). To test these theories, it is important to consider acute stress in a systematic manner.

Episodic Memory

Multiple forms of memory exist and have been studied across a range of contexts and samples (Squire, 1993; Tulving, 1987). The present study concerns youth's ability to remember prior personal experiences, a type of long-term memory often referred to as episodic or

[1] While memory for negatively valanced stimuli (e.g., words and or photos) may prime negative emotions, they do not unfold over time, therefore they will not qualify as an "event" for the sake of this study. Furthermore, we required studies to involve a dynamic event for the sake of ecological validity, eliminating slideshows paired with stories.

autobiographical memory. Episodic memories are explicit recollections of personal experiences placed in time that include the "who, what, and where" details of the experience (Fivush 2011; Nuttall et al., 2014). Autobiographical memories are a form of episodic memory that "move beyond representing what happened (i.e., episodic memory) to what happened to *me*" (Fivush, 2011, p. 562). Both episodic and autobiographical memories are commonly referenced in investigations of stress and memory. In applied studies that hope to extrapolate findings to legal, clinical, and other settings, youth are typically asked about their memory for personally salient experiences (i.e., their episodic memory is tested; Goodman & Melinder, 2010). These studies differ from those assessing the impact of arousal on learning and memory both in humans and animals throughout the lifespan (Green & McCormick, 2013; Hidalgo, Pulopulos, & Salvador, 2019; Payne et al., 2002), which instead test how well material learned under conditions of varying levels of arousal is retained over time. The present study focused on the former category of studies, assessing how stress may alter youth's memory for specific personal events, or episodic (often autobiographical) prior experiences.

Youth

The term "youth" is used throughout this report to refer to children and adolescents spanning a wide age range, spanning early childhood (approximately three years of age) through later adolescence (up to17 years of age). In this meta-analysis, the age range for studies to qualify was restricted to 3-17 years. The lower bound cut-off accounts for the offset of infantile amnesia or the inability to remember and verbally describe personal experiences that occurred prior to two to three years (Bauer, 2015; Neisser, 2004). For those under three, verbal memory skills are more limited, including for highly stressful events like medical procedures (e.g., Quas et al., 1999). Encoding and consolidation processes and retrieval skills are also limited (Kail, 1990), all of which contribute to minimal and possibly non-existent memories over time. To reduce effects on memory that may be associated with infantile amnesia rather than stress, studies with samples of youth under 3 were not included. At the other end, 17 was selected as the upper eligibility limit for age. Seventeen-year-olds have not yet attained the same legal status as adults in the United States, and charges for many crimes against youth (including those that may have involved exposure to trauma or stress) vary as a function of youth's legal status (18 U.S.C. § 5031). Therefore, it is of significant interest to focus exclusively on those who are not yet adults. Finally, it would be very difficult to combine studies on stress and memory that include college students, given that the designs of these studies often vary considerably from those employed with younger youth (Deffenbacher, 2004). Thus, for relevant theoretical, applied, and practical reasons, our study included samples with youth ranging from approximately three[2] to 17 years of age.

Theoretical Perspectives on Stress and Memory

Numerous theoretical perspectives have been proposed to explain how stress is associated with memory, particularly for salient stressful prior experiences. Some of the earliest and perhaps most prominent theories emerged from the field of psychoanalysis, which often invoked defense mechanisms to explain both functional and dysfunctional ways of coping with highly distressing or traumatic experiences and information that violated one's sense of self (Boag,

[2] Studies that included two-year-old children as a minimum age in their sample were contacted for effect size information with these youth removed. If this information was not available, the original effect size information with two-year-old participants included was retained, given that evidence of infantile amnesia in these samples was not present (i.e., two-year-old participants in qualifying studies remembered and were able to report on the stressful event).

2006; Freud, 1922). Two such mechanisms, namely dissociation and repression, have been highly cited as having implications for how well individuals remember severe trauma.

Freud suggested in the early 19th century that, when an idea or memory is too painful to address or consider directly, individuals may instead dissociate or disconnect the idea or memory from their conscious awareness (Erdelyi, 2006; Freud, 1922). Modern extensions of dissociation similarly argue that to cognitively avoid extreme stress, individuals disconnect themselves from reality, with this disconnection occurring either during or after the traumatic incident has unfolded. This disconnection allows individuals to avoid painful experiences or memories, or components of those memories (Foa & Hearst-Ikeda, 1996; Spiegel, Hunt, & Dondershine, 1988). Dissociation may interfere with proper encoding of information during a traumatic event if the mechanism is invoked as the event is unfolding, however, it may also interfere with proper consolidation or retrieval, insofar as the memory is poorly connected and hence difficult to access (Foa & Hearst-Ikeda, 1996; Morton, 2004).

Repression, another defense mechanism, has also been invoked to explain how stress affects memory. Repression and dissociation are sometimes used interchangeably among trauma therapists to argue for poor memory of trauma (Gleaves, 1996); however, they theoretically operate differently as defense mechanisms (Singer, 1995). Theoretically repression, unlike dissociation, occurs *only after* a traumatic event has been encoded specifically as a way of inhibiting retrieval of highly distressing or conflicting personal information (e.g., Briere & Conte, 1993). In particular, when memories for trauma are so highly distressing that they disrupt individuals' functioning, the mind may protect individuals by pushing the traumatic information outside of conscious recollection (Herman & Shatzow, 1987). Because the repressed information was encoded and is stored in some unconscious manner, it could resurface or become accessible, that is, be “re-remembered” typically only after the stress associated with the experience is removed, for instance via assistance of a trusted therapist. Without intervention, many psychoanalysts argue that memory for all or the most stressful parts of an experience may remain inaccessible (i.e., “repressed”; van der Kolk & Fisler, 1995).

Despite considerable interest in dissociation and repression as key mechanisms that lead to negative effects of stress on memory, and at times complete forgetting of significant personal traumas, scientific research has yet to find clear and compelling support for the defense mechanism operation, including their debilitating effects on memory (Goodyear-Smith, Laidlaw, & Large, 1997; Loftus, 1997; Otgaar et al., 2021). Instead, alternative explanations for seemingly completely forgotten traumatic experiences appear plausible, most notably explanations that rely on more normative mnemonic processes, like age at event (e.g., offset of infantile amnesia, rehearsal, salience) to explain evident trends in forgetting (McNally, 2005; Otgaar, Howe, & Patihis, 2022). Thus, other theories regarding stress and memory that do not invoke ideas about the unconscious mind appear more plausible and have generated varying levels of empirical support with adults.

A common assumption among current theories is that stress (also referred to as arousal) is intimately tied to attention, which in turn affects encoding, consolidation, and memory. For example, the application of the Yerkes-Dodson principal of an “inverted-U” association between arousal and performance (Teigen, 1994; Yerkes & Dodson, 1908) to stress and memory has been used to suggest that moderate stress levels (represented by the top of the inverted-U are positively related to memory, while higher and lower levels are negatively related (Deffenbacher, 1983). This suggestion is broad and has received empirical support from related literatures that have revealed moderate levels of stress are associated with improved attention, learning, and test performance, while high and low levels are associated with the opposite, that is, poorer outcomes (Anderson, 1990; Luksys & Sandi, 2011). However, most studies specifically regarding stress and episodic memory have instead targeted more refined versions of initial inverted-U models (see Christianson, 1992 for an early review).

Memory narrowing models for example assert that memory for central details of emotional events is enhanced by stress in a linear manner, whereas memory for peripheral details is diminished (Christianson, 1992; Christianson & Loftus, 1991; Reisber & Hertel, 2003). In particular, Christianson (1992) argued that stress directs attention towards details causally related to the stress-inducing aspects of an event (central details) to assess the situation and determine an appropriate response. This enhanced attention, though, comes at a cost, with details unrelated to the cause of stress (peripheral details) being ignored. Although several studies have found empirical support for differential effects of stress on memory for central versus peripheral details (Reisberg & Heuer, 2004; Rush, Quas, & Yim, 2011), a recurring concern is that what is deemed central versus peripheral is somewhat subjective and may depend on what goals are activated by discrete emotions (e.g., anger versus fear) in a particular high stress situation (e.g., Levine & Edelstein, 2009).

Another extension of inverted-U models was proposed by Deffenbacher (1994), who argued that a complex multi-dimensional continuum of arousal needs to be considered when evaluating how arousal may relate to memory. Using Tucker and Williamson's (1984) attentional control model and Fazey and Hardy's (1988) catastrophe model, he laid out predictions concerning when memory for specific aspects of an arousing environment will be enhanced or inhibited in response to stress. The two models make predictions regarding how 1) perceived threats guide attention to details in the environment based on whether they activate an orienting or defensive response to stimuli (Tucker & Williamson, 1984) and 2) how cognitive anxiety and physiological arousal work in complex ways to predict later memory performance for these details (Fazey & Hardy, 1988). Because the integration of these models is complex and multi-dimensional, a full discussion of potential outcomes is beyond this review. However, of relevance to this meta-analysis, Deffenbaucher makes a few predictions. First, when arousal is high but personal threat and cognitive anxiety are low, which Deffenbacher (1994) argued would be the case in most laboratory studies of stress and memory with adults, the relation between arousal and performance should be positive, although some hints at an inverted-U may as well emerge. Second, when arousal involves high levels of personal threat and cognitive anxiety, which Deffenbacher argued could be the case in studies of individuals memory for naturally occurring stressors (e.g., medical procedures), attention for threat enhancing details, and therefore memory for these details, should be enhanced up until a certain point. Finally, at extremely high levels of arousal, defense processes may be activated in response to threats, leading to a dramatic reduction in attention and resulting in what Deffenbacher labeled, "catastrophic memory failure."

Deffenbacher and colleagues (2004) found some evidence to support his predictions in a meta-analysis evaluating the effects of stress on eyewitness memory reports. Across 35 studies concerning eye-witness memory, high levels of stress in response to mock crimes (either via slides, videos, or live events) were negatively related both to the accuracy of individuals' ability to identify key witnesses in line ups and ability to recall crime-related details. Furthermore, the overall negative relation between stress and eyewitness identification accuracy was stronger in more ecologically valid conditions that likely induced a defensive response that may lead to catastrophic memory failure (*h* = -.36) than in laboratory recognition tasks that most likely activated an orienting response (*h* = -.10).

Finally, although perhaps less of a formal theory per se, the field of neurobiology and memory has laid out how activation of multiple neural regions either during exposure to a stressor or resulting from stress induction affect memory, attention, and learning (Godoy et al., 2018; McGaugh, 2013; Rudy, 2008). Acute stress exposure leads to increased activation of the amygdala, anterior hippocampus, and entorhinal cortex, all neural regions that have strong and direct links to memory encoding and consolidation processes (Cahill & McGaugh, 1998; McGaugh, 2004). Activation of these regions should lead to enhanced encoding and consolidation, and hence improved memory, a possibility confirmed by empirical research. Arousal elicited either by exposure to emotional stimuli, such as fear-inducing videos and cold-pressor tasks (e.g., Cahill et al., 1996; Dolcos et al., 2004; Storbeck & Clore, 2008) or by administration of synthetic hormones that induce arousal (e.g., Cahill & Alkire 2003; Maheu et al., 2004), enhances learning and memory for a wide range of emotional and neutral information (LaBar & Cabeza, 2006). Although in most of these studies the stress induction procedures are not causally related to the to-be-remembered information (which is the typical design of eyewitness types of investigations of stress and episodic memory), findings nonetheless suggest that heightened arousal should improve memory.

To summarize, multiple theories have been proposed to explain how stress affects memory. Yet, these theories often posit dramatically different directions of these effects. Some suggest that stress should inhibit memory, especially at very high levels (e.g., disassociation, catastrophic memory failure), while others suggest that high levels of stress or arousal should improve memory, particularly for information directly relevant to the cause of the stress (e.g., memory narrowing, emotionally enhanced memory). It is possible, via brief scan of literature with adults, to identify studies that provide empirical support for each of the theories and models. However, as discussed next, none of the models has directly taken development into consideration[3]. This raises important questions concerning how developmental processes that affect stress responses, encoding, consolidation, and retrieval of information impact the relation between stress and youth's memory, and whether any of the aforementioned models are uniquely valuable in explaining empirical findings in the developmental literature.

Developmental Considerations

Changes in both stress responses and memory occur across childhood and adolescence, and these changes may well affect how youth respond during, attend to, rehearse, and later remember prior experiences including those that are salient and stressful (Fivush, 2011; Zimmer-Gembeck & Skinner, 2011). For instance, what young children consider central during a stressful experience may well differ from what older children, adolescents, and adults think is central (Goodman & Quas, 2018; Quas et al., 2000). Likewise, although most neural structures implicated in stress responsivity and basic memory processes are well-developed early in childhood, the connections among these structures may not be, thereby potentially affecting stress responses, memory, and their relations in developmentally unique ways (Alexander & O'Hara, 2009). Accordingly, caution needs to be taken when attempting to simply apply existing theories to questions concerning the effects of stress on youth's memory. Empirical findings concerning the links between stress and memory across development reveal the need for this

[3] The meta-analysis conducted by Deffenbacher et al., (2004) did include both youth and adults, however unique impacts of development were not considered in the model given that youth were collapsed into one large age group.

caution, as they vary considerably across and even at times within investigations, as discussed shortly.

Stress and Episodic Memory Across Development

An impressive body of scientific research has examined how well children remember a range of stressful experiences, including those that have taken place independent of the research itself and those contrived by the researchers. Across and within this research, stress has been measured and at times manipulated in a variety of ways. Likewise, and again both across and within studies, memory has been measured via multiple indicators. Next, these studies are reviewed. For heuristic purposes, studies are divided into the two aforementioned types. Naturalistic studies are comprised of investigations concerning how well youth remember personal events they endure regardless of the research. Examples include unanticipated injuries (Peterson & Bell, 1996), medical and dental procedures (Brown et al., 1999; Lee 2012), and even swimming lessons (Price & Connolly, 2007). Analogue studies involve testing youth's memory for activities the researchers created. These contrived events most often take place in controlled laboratory settings and include, for example, youth giving surprise speeches and completing difficult math in front of evaluative adults (Quas et al., 2014), experiencing unexpected fire alarms (Imhoff, 2000; Quas, Bauer, & Boyce, 2004), or watching fear inducing videos (Quas & Lench, 2007). At times, analogue (and a few naturalistic) studies vary the to-be-remembered events to create high and low stress experiences (e.g., Goodman et al., 1991; Quas et al., 2014). This experimental manipulation allows for some causal inferences to be drawn regarding how stress *affects* youth's memory, as opposed to simply evaluating how stress during an event and memory of that event are correlated.

Operationally, stress has been measured using a range of indicators. Some studies have included self-report assessments of stress. Youth have been asked to report on their stress levels using scales, for instance, by reporting on a 5-point scale ("not at all stressed" to "extremely stressed") how distressing an experience was (Chen et al., 2000) or by selecting which face (frowning, neutral, or smiling) most closely matched how they felt during the stressful event (Imhoff, 2000). Other investigations collect ratings of youth's stress levels by others, such as medical professionals, research assistants, or parents who observed the youth during the stressful event or know about the youth's experience. Some such reports required observers to report on youth behavior (e.g., crying, screaming; Salmon et al., 2002) as the event unfolded, and other reports asked observers to provide ratings of the child's stress that were not specific to particular behaviors. Parents, for example, have been asked to rate their youth's anxiety during an event on a Likert scale (Lee, 2012; Patel 1997), at times during or immediately after the to-be-remembered stressful event but at other times weeks or months later. In a few investigations, ordinal scales (high, medium, low, for example) reflecting proximity to harm or danger have also been considered (e.g., Bahrick et al., 1998).Finally, some studies have collected what some have argued are objective measures of stress, or at least measures that are not as easily manipulated or subject to potential response biases as self and other report measures, namely physiological indictors (Quas & Klemfuss, 2013). Physiological markers of stress included measures such as cortisol, heart rate, and pre-ejection period (a cardiac measure believed to index activation of the sympathetic nervous system). Typically, these response values are averaged across the stressful event, and a baseline measure is subtracted from that average to create a reactivity or difference score indexing the level of physiological arousal (e.g., Chen et al., 2000; Quas et al., 2005).

Memory, as mentioned, has also been operationalized via multiple indicators which separately or in combination tap amount and accuracy. Amount, or the quantity of information reported, includes such indicators as the total number of words provided or the total number of "details" provided, most often in response to recall or open-ended prompts (e.g., Bahrick et al., 1998; Klemfuss, 2013). Accuracy refers to the veracity of youth's reports. To code for accuracy, though some record (ideally an objective record, although at times, parents' memory is used as the record) is required against which youth's report can be compared. Accuracy indicators include the number of correct details reported, at times divided by the number of total details reported, or the proportion of correct responses to direct or recognition (i.e., short-answer, such as yes/no) questions (Alexander et al., 2002; Merritt et al., 1994). Amount and accuracy measures may be separable, but such is atypical, given that many studies' measures reflect a combination of both. For instance, many sum or proportion scores involve counting the number of correct features (amount) that youth reported about an event based on a predetermined checklist of correct objective features (accuracy) (e.g., Peterson et al., 2010; Quas et al., 2006). Thus, caution is warranted in attempting to separate and analyze separately measures of only amount or only accuracy.

Naturalistic Studies

At perhaps the broadest level, studies relying on naturally occurring stressful experiences as the to-be-remembered event suggest that youth can report many specific and accurate details about these experiences (Ornstein, 1995), including after delays spanning many years (Sales et al., 2005; Peterson, 2010). Thus, in contrast to some theoretical models (e.g., dissociation, repression), complete memory failure for highly distressing events has not been observed in children or adolescents, at least so long as the event occurred after the offset of infantile amnesia, (Quas et al., 1999). Yet, regarding precisely how stress relates to memory, findings vary, regardless of whether memory is reflected in amount, accuracy, or their combination.

Among naturalistic studies that have compared memory between low and high stress groups, some findings point to potentially positive effects, while others point to non-significant or even negative effects. Brown et al., (1999), for example, compared memory for medical procedures between two groups of 3-7 year olds. One group had experienced a voiding cystourethrogram fluoroscopy (VCUG), a highly salient and arguably distressing procedure that involves urethral catheterization and the requirement that youth void (urinate) while radiological images of their bladder are taken by medical personnel. The other group had experienced a routine pediatric assessment. Youth's memory for the procedures was tested a week later. Children who experienced the VCUG reported a larger number of details than children who experienced the checkup. Insofar as one can interpret the differences in memory between the groups as being primarily due to the VCUG being much more stressful, stress seemed to have enhanced memory. In a more controlled design, Goodman et al., (1991) compared memory in children ages 3-7 who had experienced either a venipuncture or a temporary tattoo as a part of a pediatric examination. Here, all children had experienced largely the same event, with the exception that one had their blood drawn whereas the other had a drawing placed on their arm. Other characteristics (e.g., age, sex, race, delay, lab technician, and time spent in the room) were controlled to make sure they were similar between the groups. Findings suggested that, although children who had blood drawn were more visibly distressed, their memory for the examination when tested three days later did not differ from that of children who received the pretend tattoo in terms of the correct amount of detail provided in free recall or the proportion of recognition questions answered correctly.

Among correlational naturalistic studies of stress and memory, consistent with Goodman et al. (1991), many report no significant associations (e.g., Chae et al., 2014; Lee, 2012; Melinder et al., 2013). This includes in analyses of memory among only the subset of youth in the Brown et al. (1999) who underwent the VCUG. Pediatrician ratings of the youth's stress during the VCUG were unrelated to the amount of correct information they recalled about what had happened. Lee (2012) observed 4-10 year olds during a dental exam, rated their behavioral distress, and measured their heart rate and vagal tone as the exam unfolded. When the youth's memory for the exam was tested later that day, no significant correlations emerged between any of the measures of arousal and the total amount children recalled about the exam. Price and Connolly (2007) also reported non-significant differences in memory (i.e., amount correctly recalled) between 4-5 year olds rated as anxious versus non-anxious during swim lessons that occurred the week before. Finally, Melinder et al. (2013) had a research team code behavioral stress responses in youth (ages 3-13) as they were removed from their home by social workers due to suspected maltreatment. One week later, the team assessed youth's memory for their removal. No significant associations emerged between stress and youth's responses to recall or recognition questions.

Yet, other studies have reported negative relations between stress and memory. Merritt et al. (1994), for instance, also assessed memory for the VCUG among youth ages 3-7. The researchers rated youth's behavioral stress and had physicians rate the youth's fear as well. Greater stress according to the physicians' ratings was related to a decrease in the total amount of correct information youth provided in a response to free recall and recognition questions immediately after the procedure. Likewise, greater stress according to the behavioral indicators was negatively associated with the same memory measures after a 6-week delay. Peterson (2010) reported a similar negative relation. Parents' reports of 2-13 year old's stress levels when they endured an injury resulting in an emergency room visit were negatively associated with the amount and accuracy of youth's responses to free recall/recognition questions about the injury a week later. Finally, Chen et al. (2000) found that greater stress during a lumbar puncture procedure (according to both physician assistants' general ratings and behavioral indices) was associated with decreases in the accuracy of 3-18 year old youth's responses to recall and recognition questions about the procedure.

Of note, one study reported an inverted-U relation. Bahrick et al. (1998) assessed 3-4 year old's memory for Hurricane Andrew, a devastating hurricane that hit the southeastern region of the US in 1992. The research team's indicator of stress was a three-point Likert scale reflecting the amount of damage to the youth's home (low, moderate, severe), and the team assessed the children's memory two to six months after the hurricane occurred. Children whose homes had endured low and severe damage reported fewer details (reflected in the number of propositions about the hurricane) than did children whose homes had moderate damage.

On one hand, the variability in findings makes it difficult to identify consistent trends. On the other hand, some hints at potential patterns may be discernable or at least possible, laying the foundation tentative hypotheses. First, there was no evidence of complete forgetting of highly distressing personal experiences. Thus, neither stress-specific mechanisms nor general forgetting lead to non-existent memories. Second, many observational, behavioral, and physiological indicators of stress are either negatively or non-significantly related to memory for naturally occurring stressors, regardless of whether memory amount or accuracy is being assessed (e.g., Brown et al., 1999; Lee 2012; Merritt et al., 1994; Peterson et al., 2010). And third, although older youth consistently outperform younger youth in how much and how accurately they remember prior experiences, no consistent age-related differences in the associations between stress and memory have emerged.

Analogue Studies

Although studying youth's memory for naturally occurring distressing experiences provides a unique window into how youth remember particularly salient, personally meaningful, and often threatening stressful experiences, the experiences are not always documented. For instance, parents may be asked to confirm whether details reported by youth are true. However, adults' memories are also subject to forgetting or errors and thus parental reports should not be taken as ground truth (Hyman & Loftus, 1998; Patihis et al., 2013). More important, with naturally occurring stressors, youth cannot be randomly assigned to condition. As such, the causal links between stress and memory cannot be determined. Instead, studies only report on the relations stress and memory, not the effects of stress on memory (see Goodman et al. 1991, for an exception). In addition, studies vary in how well they were able to assess youth's stress, with some relying on retrospective ratings provided by others, and a few relying on youth's own reports (but see Chen et al., 2000; Sales et al., 2005). A small number of studies has included physiological indicators of arousal (Lee et al., 2012; Merritt et al., 1994). However, these may have had only limited baseline measures or may not have controlled for time of day (e.g., Merritt et al.,1994), which likely affected the reliability of indicators of physiological stress responses (e.g., salivary cortisol levels; Clements, 2013) and hence their association with memory.

Analogue studies can address some of these limitations, even though the absolute level of stress youth experience during to-be-remembered events is often substantially lower. In analogue studies, researchers can also often videotape or document precisely what occurred (Lee 2012; Salmon, 2002), and youth's memory can be evaluated for accuracy. In some analogue studies, stress has been experimentally manipulated during a to-be-remembered event, for instance, by exposing youth to a high and low stress version of a similar task (Klemfuss et al., 2013; Quas et al., 2014). Youth's experiences as such are held fairly constant aside from the stress manipulation. When memory for the event is tested later, strong causal inferences can be drawn about stress's effects on memory. Other analogue studies, though, have followed an approach similar to that of many naturalistic studies, exposing youth to the same mildly stressful analogue or laboratory event (e.g., a fire alarm) while measures of their stress or arousal are collected (Quas et al., 2005). After delays varying from a few minutes to weeks (Imhoff et al., 2000; Quas et al., 2012), youth's memory for the event has been tested, and correlations have been computed between the youth's stress responses and their memory.

An example of both designs can be found in assessments of youth's memory for a modified version of the Trier Social Stress-Modified (TSST-M). The TSST is a widely used laboratory activity requiring participants give a speech and complete mental arithmetic in front of a camera and highly evaluative observers (Kirschbaum et al., 1993). Both the TSST and TSST-M reliably induce behavioral and physiological stress responses across age, beginning at 8-9 years (Buske-Kirschbaum et al., 1997; Kirschbaum et al., 1993; Yim et al., 2010). Yim and colleagues (2015) created a second version of the TSST-M, which they termed the low stress TSST-M, that maintained the same activities (i.e., speech and math) but removed the most social-evaluative aspects, which are those believed to underlie and cause exaggerated stress responses (Dickerson & Kemeny, 2004). The low stress TSST-M thus was highly similar in objective features as the standard or high stress TSST-M, but the youth's level of arousal was significantly reduced, reflected across multiple markers of arousal (e.g., self-report, HPA axis activation, sympathetic arousal) (Yim et al., 2015). In some investigations, Quas and her colleagues have compared memory between youth who experienced the standard high stress version and the low stress version (Klemfuss et al., 2013; Quas et al., 2014). In others, they have computed correlated between youth's arousal during the standard TSST-M and their later memory for the TSST-M (e.g., Quas et al., 2011; Quas & Dickerson, 2019).

Studies that experimentally manipulated stress using the TSST-M have for the most part failed to uncover any significant differences in memory between youth who experienced the high and low stress versions following a 2-week delay (Klemfuss et al., 2013; Quas et al., 2014). Klemfuss et al. (2013), for example, reported no differences in the total number of words reported in response to free recall prompts by either 8-to-10 and 12-to-14-year olds. Quas et al. (2014) conducted a more comprehensive analysis of the same data and examined both amount and accuracy of youth's memory. No effects of the stress manipulation emerged when the number of correct details youth provided in free recall was examined. However, when responses to recognition questions were considered, an interaction between stress and age emerged: 12–14 year olds who experienced the low stress TSST-M provided a greater number of correct responses than did 12-14 year olds who experienced the high stress TSST-M. Yet, when responses to *misleading* recognition questions were examined, that is, question which explicitly suggested incorrect information, the opposite pattern occurred: 12–14 year olds who experienced low stress TSST-M were less accurate than those who experienced the high stress TSST-M. Thus, across experimental studies, stress does not appear to affect memory.

In contrast, correlational studies have revealed some significant trends, specifically those suggesting that stress and memory are positively related. For example, greater physiological arousal (e.g., cortisol reactivity) during the TSST-M has been associated with better recall accuracy in youth ages 7-14 years (Quas et al., 2012). Further, Quas, Bauer, and Boyce (2004) exposed children ages 4-6 to a series of laboratory challenges, including a brief fire alarm incident, while monitoring their cortisol responses so that reactivity difference scores, reflective of physiological arousal during the alarm, could be calculated. Larger reactivity scores were marginally positively associated with increases the accuracy of youth's responses to recognition questions about the alarm asked shortly after it occurred. A similar pattern, namely a positive association between stress and memory for a fire alarm was reported by Quas, Carrick et al. (2006) when stress was reflected in sympathetically driven arousal. Finally, Chae et al. (2018) tested 3-5 year old's memory for an age-appropriate modification of the Strange Situation, which involved brief mildly arousing episodes of separations and reunions between children and a parent (Cassidy & Marvin, 1992). Greater distress in the children during the episodes, reflected in behavioral ratings by research assistants, was associated with greater accuracy when children were asked recognition questions about what happened.

Some analogue study findings, though, have included non-significant or negative associations between stress and memory. In the investigation by Chae et al. (2018) just mentioned, for example, no significant associations were uncovered between stress and the amount of correct information youth provided in free recall. Similarly, Quas and Dickerson (2019) found no associations between cortisol reactivity levels during the standard (high stress) TSST-M and 8-14 year old's later recall or recognition question performance. When Imhoff (2000) initiated an unexpected fire drill during a preschool "science experiment," increases in self-reported stress among 3-5 year olds was associated with decreases in the accuracy of their responses to both recall and recognition questions. Finally, in the aforementioned study of children's memory for a brief fire alarm by Quas et al. (2006), stress reflected in the *withdrawal* of parasympathetic regulation was negatively associated with memory in older (e.g., 6-8) but not younger (e.g., 4-5) children.

In summary, findings among analogue studies, like their naturalistic counterparts, also vary, with hints at potential trends. First, studies that included manipulations of stress during analogue controlled activities have for the most part have not uncovered group differences in memory. Thus, main effects of stress on memory per se do not appear likely, regardless of whether stress has been measured via self-report, other-report, or physiological indicators and regardless of whether amount or accuracy of memory has been examined.

Second, when continuous measures of stress have been collected during mildly to moderately arousing analogue activities (e.g., fear inducing videos, fire alarms. TSST-M), stress at times appears positively associated with memory both as reflected in the amount of correct information recalled and accuracy to misleading questions (Quas et al., 2006, Quas et al., 2012, Chae et al., 2018). This pattern has emerged most often when stress was indexed physiologically (for exceptions, see Quas & Dickerson, 2019). In one study that included self-report measures of stress (Imhoff, 2000), negative relations with memory accuracy were reported. Finally, as reported in naturalistic studies, both the amount and accuracy of memory improve with age. In a few analogue studies, as well, age interacted with stress to predict memory, but the direction of these associations varied across memory measures (e.g., Quas et al., 2006, Quas et al., 2014).

PRESENT STUDY

Although there are some suggestions of links between stress and memory across extant research on youth, they are difficult to distill. A particularly useful way to synthesize these diverse findings while accounting for potentially important moderators of the relation is via meta-analysis. Such is the overarching purpose of the present study. Specifically, this meta-analysis evaluated the relation between stress at the time of a to-be-remembered stressful event (either measured or categorized into high and low stress groups), and subsequent memory for that event among youth ranging from approximately three to 17 years of age. Memory could be reflected in amount, accuracy, or most commonly, in some combination of the two.

Hypothesis for the overall model

Based on the highly variable findings evident in extant research, stress during a stressful event was not expected to be significantly related to youth's memory of that event.

Moderators

In contrast to the predicted null hypothesis (i.e., no relations) regarding the overall relation between stress and memory, several moderators were anticipated to predict specific relations. These moderators emerged in the literature review, which revealed considerable heterogeneity in characteristics of studies concerning stress and memory in youth. The most notable was that of the age of the youth in the samples. Others included the types of to-be-remembered event, how both stress and memory were measured, and the delay between the event and the memory test. By testing whether these characteristics serve as important moderators, the meta-analysis had the opportunity to provide nuanced insight into how stress and memory are related across childhood and adolescence.

Moderator Hypothesis 1: Stress Measurement

Hypothesis 1: Physiological measures of stress will be positively associated with memory, while other measures (self-report, other-report, objective environmental indices) will be non-significantly associated with memory.

Stress Measurement. How stress during the to-be-remembered event was operationalized varied considerably, both across and within studies. As previously described, measures have included self-report, other-report, physiological, and even environmental indicators of stress. Some researchers have argued that both youth's own and adults' ratings of the youth's stress levels, but also environmental indicators (e.g., level of damage) may be more subject to reporting biases and hence less reliable markers of stress than physiological indicators of arousal (Quas & Klemfuss, 2014). First, observers' own feelings may lead to misinterpretation of youth's behaviors. For instance, parents' reactions to their children's behaviors during a stressful medical procedure are associated with other characteristics in parents, such as their own attachment style (Edelstein et al. 2004), which may drive parents' perceptions of how distressed their children are (e.g., an anxious parent may believe that their child is stressed because the parent is distressed). Second, regarding self-report, youth may exaggerate their reported distress to receive validation or deny that they were aroused due to perceived social pressures or social norms that lead to expectations that are stoic or strong. And third, the labels on measures of self, other, or even environmental indicators of arousal are imposed by researchers (e.g., "extremely stressed), with no clear or consistent anchors to which the labels can be compared, leading to potential subjectivity in the scales' meanings.

Physiological indicators of arousal are not as easily controlled by individuals volitionally (Chu et al., 2021; Quas & Klemfuss, 2014) and are likely less affected by the biases or variations in anchor perceptions as are self and other report measures. Insofar as biological stress responses are linked to neural regions involved in basic memory processes, greater physiological arousal during a to-be-remembered event should be positively associated with memory for that event, as has been reported in several studies (e.g., Quas et al., 2007, Quas et al., 2012) and as has been reported in studies of arousal and learning or memory in adults (LaBar & Cabeza, 2006).

Moderator Hypothesis 2: Age

Hypothesis 2: The association between stress and memory will vary with age such that among younger youth, stress will be negatively or non-significantly related to memory, whereas among older youth (e.g., adolescents), stress will be positively related to memory.

Age. Across developmental studies, regardless of stress, the most robust predictor of memory is that of age (Fivush 2011; Ghetti & Lee, 2011; Ornstein, 2014). Yet, more central to the current investigation is how the effects of stress on or associations between stress and memory vary as a function of age. Youth across wide age ranges have been included in studies of stress and memory (e.g., Chen et al., 2000; Imhoff, 2000; Quas et al., 2014), and some findings, along with developmental theories of stress, regulation, and memory, suggest that age may matter. It is possible, for instance, that age differentially impacts the content of what is encoded under stress. Younger children tend to have more limited self-regulation skills than older children (Silvers et al., 2012; Skinner, & Zimmer-Gembeck, 2007) and therefore may rely more on outside sources of help when distressed (i.e., parents and caregivers). Although older youth may experience similar levels of stress, they may be better able to direct their attention towards their own situation to determine how best to self-regulate and respond. If this in fact the case, older youth may better encode details from the surrounding environment during a stressful experience than younger youth do, the latter of whom instead may encode details regarding their parents or others who are aiding in regulation. This developmental shift in attention should enhance encoding as youth age increases.

Moderator Hypothesis 3: Study Type

Hypothesis 3: Stress will be negatively or non-significantly related to memory in naturalistic studies but positively related to memory in analogue studies.

Study Type. The events that youth experience in naturalistic studies have ranged from moderately arousing (e.g., swimming lessons; Price et al., 2007) to highly distressing events, the latter of which could be considered traumatic to some if not many youth (e.g., VCUG procedures, removal from the home following maltreatment; Melinder et al., 2013; Merritt et al., 1994; Quas et al., 1999). In contrast, the events that youth experience in analogue studies have typically included mildly stressful or arousing events, such as watching brief fear-inducing videoclips (Quas & Lench, 2007) or brief fire-alarm incidents (Peters, 1991). Thus, the intensity of youth's overall stress responses during naturalistic and analogue events likely varies.

Theories of the inverted-U relation between stress and memory, as well as the notion of catastrophic memory failure (Deffenbacher et al., 2004), predict improvements in memory at moderate levels of stress but impairments as stress reaches very high levels (or when stress is non-existent). Considering that extreme levels of stress associated with activation (defense oriented) stress responses have primarily occurred under naturalistic conditions (Deffenbaucher et al., 2004), one might expect to see negative relations in naturalistic studies, given that at least some youth are experiencing such high levels of stress that catastrophic memory failure occurs. Analogue studies, in contrast typically contain events that are unlikely to be personally threatening to youth, resulting in mild to moderate levels of arousal associated with an orienting in many youth (Tucker & Williamson,1984). This orienting response in analogues studies should enhance memory as stress increases from low to moderate (Deffenbaucher, 1994).

Moderator Hypothesis 4: Delay

Hypothesis 4: The relation between stress and memory will be positive when memory is assessed after short delays (e.g., within days, weeks) but non-significant when memory is assessed after longer delays (e.g., following a few months or years).

Delay. Delays between the to-be-remembered event occurring and the memory test in extant research have varied from mere minutes (Quas et al., 2006; Vandermaas et al., 1993) to months or even years later (Goodman et al., 1991; Quas et al., 1999; Sales et al., 2005). Differences in delay have implications for how stress relates to youth's memory. With short delays, the most stressful experiences are likely to remain salient in youths' minds. Even if youth do not report on the event immediately (i.e., the same day), short delays of a few weeks or less may facilitate rumination, and in some instances, even narration of these experiences to close others as youth attempt to process what happened to them (Rose, 2003; Shaw, Hilt, & Star, 2019). However, as delay increases and the event becomes less central or as other personal experiences occur and become salient, youth may think about and hence rehearse the prior stressful event less often. They may also reappraise how they felt, similar to adults who tend to underestimate the intensity of their past emotional experiences over time (Kaplin et al., 2015; Levine et al., 2010). Thus, with time, youth may view a prior stressful event as less relevant to their lives, their perceptions of initial distress fades, and they may rehearse events less frequently, all of which should decrease the influence of stress on memory at long delays.

Exploratory Moderators

In addition to the hypothesized moderators, which emerged largely out of variations in prior studies, other moderators may also be important to consider. These also varied across studies, but not in a systematic manner that allowed for clear hypotheses to be generated. Thus, the following moderators were examined in an exploratory manner: how memory was measured (amount vs. accuracy), the types of memory questions asked (recall vs. recognition), whether suggestibility was present in the memory interview (yes/no), region, race, and gender.

METHOD

Literature Search Strategy

A comprehensive literature search was conducted with four main complementary strategies. To begin, an abstract search was completed in two relevant disciplinary search engines: PsycInfo and Medline. These engines were chosen for their collective ability to cover both unique and overlapping literature in both psychology and the medical field. The search was done on February 14th 2019, and updated on May 5th 2022. Table 1 shows a comprehensive list of search terms, which spanned stress, memory, and development. Stress terms included *trauma, stress, distress, arousal, emotion.* Developmental terms included *developmental, youth, adolescent, juvenile, child* and memory terms included *recall, memory, remember*. Studies that contained the phrase *traumatic brain injury (TBI)* were excluded. These two searches retrieved 2960 relevant abstracts from PsycINFO and 3485 abstracts from Medline.

Once this search was completed, additional reports were identified for screening via three methods, as follows. First, relevant reviews on the topic of stress and memory were identified in abstract and full-text screenings were retained, and their reference sections were reviewed for potentially relevant studies. From this, 26 additional reports were identified for screening. Second, a list of relevant listservs to contact for unpublished research on stress and memory was generated in consultation with experts in the field. These included Society for Applied Research in Memory and Cognition (SARMAC), APA Division 7 (Developmental Psychology), and APA Division 37 (Society for Child and Family Policy and Practice), and APA Division 41 (American Psychology-Law Society). The Society for Research in Child Development (SRCD) was also contacted based on expert suggestions, but the organization did not allow for solicitation of data.

Emails sent in April 2022 generated 7 additional reports for review. Third, all corresponding authors in the final sample of qualifying studies were contacted, and asked to provide any unpublished, or potentially overlooked published work that may be relevant to the current meta-analysis. Authors were emailed in November of 2022 and given at least one month to respond to inquiries. At least one follow-up email was sent to all authors before the communicated deadline. No additional articles or unpublished studies were received.

Table 1

Literature search procedures for electronic databases

Literature search date	**Search terms**	**Search parameters**	**Electronic databases**	**Documents retrieved**
February 14th, 2019	*"developmental", "youth", "adolescent", "juvenile", "child"* and "*recall", "memory", "remember"*, excluding "*traumatic brain injury"* and "*TBI"*	Abstracts searched using the ProQuest, and Medline engines	*PsycINFO, Medline*	5,399
May 5th, 2022	*"developmental", "youth", "adolescent", "juvenile", "child"* and "*recall", "memory", "remember"*, excluding "*traumatic brain injury"* and "*TBI"*	Abstracts searched using the ProQuest, and Medline engines	*PsycINFO, Medline*	1,046

Inclusion Criteria

Abstract Screening

The full protocol for the abstract screening can be found in Appendix A. The initial abstract screening relied on a set of inclusion criteria. If the answer was "no" to any criterion the report was not downloaded for full-text review. Inclusion criteria were as follows: 1) Is the population children, adolescents, or unknown? 2) Is there a potential quantitative measure of memory of an event or experience? 3) Is there a potential quantitative measure or manipulation of youth's stress, emotion, mood, or arousal during the to-be-remembered event? 4) Is there a typical population included in the sample? 5) If the article is a review or meta-analysis, could there be an article cited that meets any of the above criteria?

Three doctoral students practiced screening the first 100 abstracts from ProQuest and Medline. Discrepancies were rare. When they did occur, they were discussed and resolved. Next, the team divided and independently and systematically screened the remaining abstracts. If it was unclear from the abstract whether the report would qualify, the full text was downloaded and retained for further review. Reasons for failing to meet the inclusion criteria above (1-5) were noted. All reports that met inclusion criteria based on the abstract review were downloaded, resulting in 481 reports from PsychInfo and 590 reports from Medline for further review. Among these, 67 were labeled as relevant review articles and 30 were not available, resulting in 944 reports for full text review.

Full-text Screening

The complete full-text screening protocol can be found in Appendix B. Two doctoral students screened and coded all reports classifying them as qualified, unqualified, or unclear. Discrepancies between coders and uncertainties were discussed between coders to come to a final decision. Inclusion criteria were as follows: 1) Are there participants between three and 17 years of age both when the target to-be-remembered event occurred and when memory was assessed? 2) Does the report contain an actual study that contains data, more than just a single case? 3) Is there an objectively stressful or unpleasant to-be-remembered event unfolding over time[4] that the youth directly participated in or witnessed? 4) Is there a quantitative measure *or* manipulation of participant stress, emotion, mood, or arousal during the to-be-remembered event? [5] 5) Is there a quantitative measure of memory that in some way assesses the total amount of information recalled, and/or the accuracy of information reported by the youth? 6) Is the original event documented or confirmed in some way? 7) Is there a normal population? 8) Is the memory report free from the outside influences? 9) Is the full text available in English?

Information Coded in Research Reports

Data were extracted from each qualifying report via a coding protocol established in consultation with experts on stress, memory, and meta-analysis. Reports were defined as any document that was retrieved containing data from a study or series of studies that ultimately qualified for this meta-analysis. The coding protocol (see Appendix C) included report type (published vs. unpublished); sample characteristics (e.g., age, race, gender); and study

[4] Negatively valanced stimuli such as words and photos did not qualify. The TBR had to be a dynamic witnessed or experienced event.
[5] Number of events did not count as a quantitative measure of stress/arousal (e.g., total instances of abuse).

characteristics, such as study design (experimental vs. correlational), data measurement information (e.g., type of measure or manipulation for stress, type of memory measure) and other data relevant for moderator analyses. Each report was independently reviewed by the author, and 20% of the sample was coded by another trained doctoral student resulting in 94% agreement. Discrepancies were then discussed and resolved. Extractions from the remaining reports were completed by the dissertation author.

Main Stress and Memory Variables

In all qualifying reports, stress was reported as either a continuous or categorical predictor. Categorical predictors were typically ordinal (e.g., low and high stress groups) variables (Goodman et al., 1991; Klemfuss et al., 2013). Continuous predictors fell under a variety of measurement categories (e.g., self-report, other-report, physiological, etc.). The memory outcomes in each study were continuous, reflecting quantifications of amount or accuracy. For more detail on how information on stress and memory variables was extracted, see Appendix C.

Across reports, the relations between stress and memory were most often tested via correlations, regressions, or ANOVAs. When zero-order correlation coefficients were not directly available, descriptive and inferential statistics from the analyses (e.g., means, standard deviations, and subgroup sizes) were collected when possible to calculate standard mean difference scores between low and high stress groups. All necessary effect size calculations were completed both by the author and another graduate student with high level training in statistics, using the Campbell Collaboration Effect Size Calculator (Wilson, n.d). Rare discrepancies in these calculations due to human input error were reviewed and resolved.

Moderators

Memory measurement. Memory measures that qualified for the meta-analysis included those that quantified the amount of information children reported, the accuracy of their reports, or some combination of amount and accuracy. When possible, a distinction was made between amount and accuracy. Amount measures were those that only considered the total amount of information provided (e.g., total number of relevant prepositions, total number of words) without any verification or consideration of veracity of the information. Accuracy measures were those that could be differentiated as factually correct or not correct (e.g., proportion accuracy scores, sum scores based on the number of items that youth correctly reported from a pre-determined checklist).

Stress type. Five categories of stress measures were identified: self-report, other-report, checklist, environmental, and physiological. For moderator analyses, these were combined in two ways. First measures were dichotomized into physiological vs. all other non-physiological measures. This distinction was made to test the hypothesis that physiological measures of stress and non-physiological measures of stress would be differentially related to youth's memory. Second, measures were trichotomized into self-report, other-report or observation, and physiological to explore whether ratings of stress that came from the youth directly versus from trusted others diverged from each other in ways that also differed from physiological measures. Environmental indicators were excluded from the latter categorization given that very few effect sizes existed within this category.

Age. To evaluate age as a moderator of the relation between stress and memory, the average age of the sample was collected from each study (it was not possible to create a dichotomous age group, such as children versus adolescents, because of the way that age varied and was examined in the individual reports).

Study Type. Naturally occurring (e.g., accidental injury, necessary dental procedure) and analogue (e.g., TSST, stress inducing videos) stressful to-be-remembered events were distinguished by whether the event took place regardless of research (naturally occurring) or was induced for the sake of research (analogue). Study type was then analyzed as a potential moderator.

Delay. Although the delay between the stressful event and the memory test is continuous in nature, it was not possible to calculate a continuous delay variable. Instead, delay was divided into four timeframes: very short (immediate or less than one day), short (one day to two weeks), moderate (two weeks to 1 month), and extended (over one month). This was the most nuanced categorization possible given the availability of delay information in each report .

Question type. Based on extant literature concerning question type and youth responses (Lamb et al., 2011; Lyon, 2014), three question type categories were created: recall, recognition, or both. When reports included effect sizes separately by question type (recall, recognition), these effect sizes were retained in the analyses. Any additional effect sizes that combined measures were excluded as these would have been redundant with the specific question type effect sizes. When studies combined question types and reported these effect sizes only, the broader ones were included. In other words, the only time when effects involving combination measures (recall + recognition) were retained is when effects separated by question type were not available in the report.

Suggestibility. Some of the memory questions in qualifying studies included suggestive questions, and others did not. Thus, memory outcomes were categorized dichotomously by whether suggestibility components were present.

Report characteristics. To evaluate report characteristics as moderators, demographic details were categorized. The proportion of the sample that was white, the proportion of the sample that was female, the location in which the study took place (North America, other), publication year, and publication status (published/unpublished) were all considered.

Effect size estimation

Correlations (*r*) were used to quantify the relation between stress and memory in youth. Most correlations available in reports were Pearson's correlations, although a few studies reported Spearman's correlations and/or partial correlations. Both Pearson's correlations and Spearman's correlations (while rare) were examined. The rational for retaining Spearman's correlations was twofold. First, similar to Pearson's *r,* Spearman's rho quantifies the strength and direction of the association between stress and memory broadly without controlling for other variables. Second, Spearman's rho coefficient (r_s) is simply Pearson's *r* between ranks (e.g., categories on a Likert scale) and has approximately the same sampling error variance (Hunter & Schmidt, 1990). Therefore, Spearman's rho is a conservative estimate of Pearsons *r* that does not put the study at risk for Type 1 error. Partial correlations, which were reported in one study, were eliminated because they controlled for variables (most often age) that may contribute to some of the variation in the relation between stress and memory and hence may not reflect the same broad association between stress and memory as Pearson's *r* and Spearmn's Rho.

In reports that only included standard mean difference information, *d* was converted to *r*. The decision to convert all *d* indices to *r* and not vice versa was made for both theoretical and methodological reasons. First, although some studies categorized youth into high and low stress groups and compared memory between groups (Goodman et al., 1991; Klemfuss et al., 2013), the purpose of the current meta-analysis was to understand how stress may influence memory across multiple levels, not just at high versus low levels. Second, some studies that categorized youth into high and low stress groups first collected continuous or more nuanced measures of stress and then used these indicators to form high and low stress groups (Bahrick et al., 1998; Imhoff, 2000). These studies, though, were interested in how incremental increases in stress were related to memory. And third, even when studies that assigned or created high and low stress groups, what constituted "low" and "high" was not consistent across studies. Thus, by converting *d* to *r*, it was possible to assess the relation between stress and memory in a continuous manner. Once all effect sizes were in the form of a raw correlation, they were transformed into z scores (r_z) to normalize their sampling distribution and stabilize their variance, as is standard in meta-analysis (Hedges & Olkin, 1985).

Analytic Plan

Analyses were conducted using the metafor package in R (Viechtbauer, 2010). A random-effects multivariate approach with robust variance estimation was employed. Many of the eligible studies included multiple measures of stress and multiple memory outcomes from each participant (e.g., Lee 2012; Quas et al., 2014), resulting in dependent effect sizes. Because conventional meta-analytic procedures assume that effect sizes are independent, a multivariate approach was taken to deal with dependencies (Cheung, 2019). Robust variance estimation (RVE), a random-effects meta-regression technique (Hedges, Tipton, & Johnson, 2010) allows for the inclusion of statistically dependent effect sizes within the meta-analysis without specific knowledge regarding correlations between effect sizes (Pustejovsky & Tipton, 2022); based on conventional standards, a correlation of .80 was assumed across models. A random effects model was chosen given the assumption that important theoretical and methodological moderators have created a true variation in the relation between stress and memory among youth across studies (Borenstein, Hedges, & Rothstein, 2007). Finally, Cochran's *Q*, which indicates whether there is more variability around the average effect size than can be explained by estimation or sampling error, was used to test for the heterogeneity of effect sizes and offer an empirical rationale for the exploration of our predetermined and exploratory moderators.

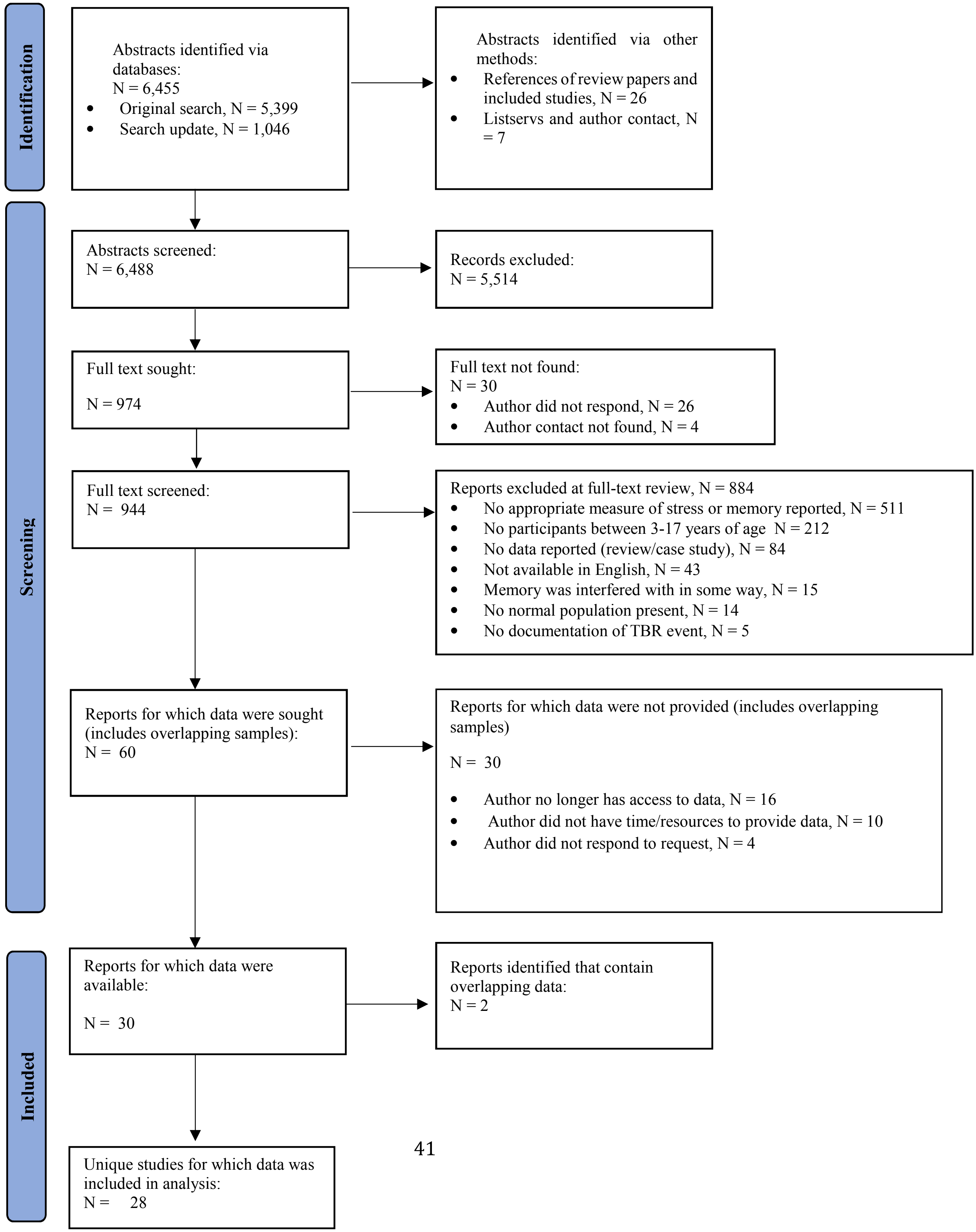
RESULTS

Studies in the Meta-Analysis

In total, 944 full-text reports were reviewed for this meta-analysis, with 884 of them excluded, leaving 60 unique reports from which data were sought. The data included potentially overlapping samples from 32 corresponding authors. When necessary effect size information was not available in a study, corresponding authors were contacted. If corresponding author information was not found, co-authors or dissertation chairs were contacted instead. All authors were contacted a minimum of 2 times to request data. Between data available in reports and data retrieved from authors, a total of 28 unique studies were included in final analyses (see Fig 1). These analyses included a total of 2,082 unique participants ranging from 3 to 17 years of age. Appendix D includes the list of studies in the final sample along with moderator characteristics. Five were unpublished dissertation studies and 23 were studies in peer reviewed journal publications. The year in which the reports were made available either via publication or dissertation/formal report ranged from 1991 to 2019.

Figure 1

PRISMA flow diagram



Overall Model

All effect size statistics reported are based on RVE adjusted models unless otherwise specified. For these analyses, a negative correlation indicates that stress is associated with poorer memory. Across the 28 studies and 177 correlations, the effect size between stress and memory in our sample was very small (r_z = -.01) and non-significant [*t* (176) = -0.44, *p* = .66)]. While there was little evidence of heterogeneity at the study level, there was some evidence of heterogeneity at the effect size level: [*Q*(176)= 1028.96, *p* <.0001; Tau (effect size) = 0.02; Tau (study) = 0.00; 95% PI (-0.32, 0.30)]. This variability at the effect size level was expected and suggests that methodological and theoretical variables (moderators) may well be influencing the relation between stress and youth's memory. The prediction interval (PI) indicates that 95% of correlations included in this meta-analysis fell between -.32 and .30.

Covariates

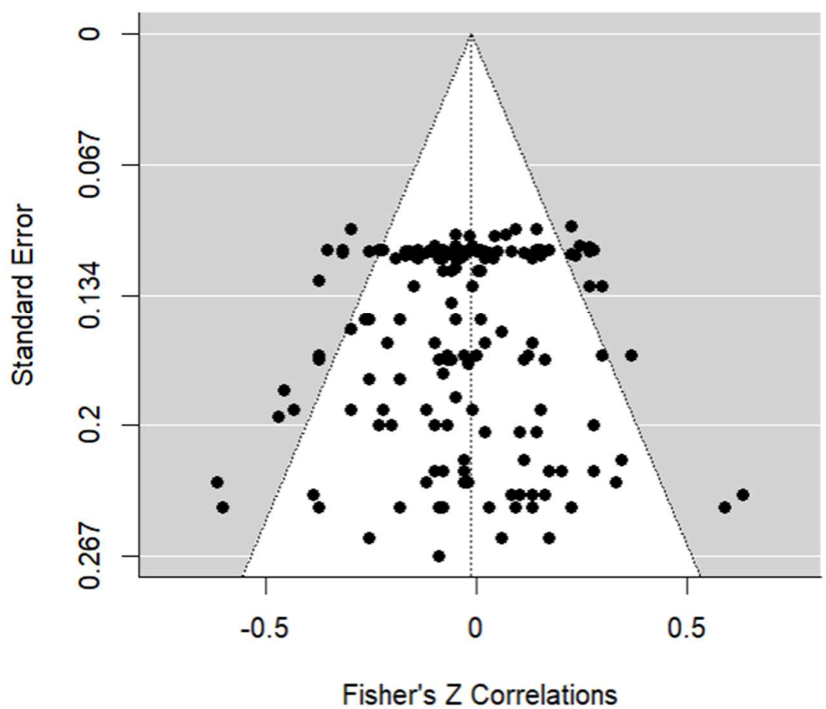
Before turning to formal tests of the hypothesized and exploratory moderators both publication year (continuous), and publication status (unpublished vs. published) were tested to establish whether they should be included across models as covariates. The overall relation between stress and memory did not vary as a function of publication year [*F*(1,175) = 0.03, *p* = 0.86]. For every one-year increase in publication year there was a very small (nearly zero) positive, and non-significant increase in the correlation between stress and memory [*b* = 0.00 , *t*(11.40) = 0.50, *p* = .63]. Furthermore, the relation between stress and memory did not vary as a function of publication status [*F*(1,175) = 0.11, *p* = 0.74]. Average correlations between stress and memory for published studies [r_z = -.02 , *t*(16.51) = -0.73, *p* = .48] and unpublished studies [r_z = 0.00 , *t*(3.60) = -0.03, *p* = .98] were both small, negative, and did not differ significantly from zero. A pairwise comparison also indicated that average correlations between published and unpublished studies also did not significantly differ from each other [$b = 0.02$, $t(4.67) = 0.51$, $p = .64$]. Non-significant differences in the overall relation between stress and memory between published and unpublished studies are important in the context of publication bias, a phenomenon evaluated more thoroughly in the next section. Given that neither publication year nor publication status emerged as significant, they are not considered further, and moderator analyses were conducted without adjustment for covariates. Table 2 provides the overall, covariate (tested), and moderator results of the meta-analysis.

Publication bias

Regarding publication bias, studies that find significant results and demonstrate larger effect sizes are more likely to be published than studies that demonstrate null or weak yet significant findings (Thornton & Lee, 2000). This phenomenon may lead to a biased sample of studies at the meta-analytic level, which overestimates the overall effect size. To address potential publication bias methodologically, unpublished grey literature was sought via multiple relevant listservs and through direct emails to corresponding authors whose published studies emerged in our literature search. To address potential publication bias statistically, publication status was evaluated as a covariate. As indicated above, the relation between stress and memory did not significantly vary as a function of publication status. To address potential publication bias visually, the funnel plot of effect sizes shown in Figure 2 was evaluated for symmetry. Though funnel plot asymmetry should not be directly equated to publication bias, reporting bias across studies can lead to asymmetry in a funnel plot of effects (Sterne et al., 2011). As one can see, no evidence of exaggerated asymmetry among effect sizes was present. Thus, in combination, there is no compelling or converging evidence of publication bias at the meta-analytic level.

Figure 2

Funnel Plot of Effect Sizes



Planned Moderators

Memory outcome

In the overall model, measures of memory amount and accuracy were combined. Yet, it was also possible that the associations between stress and memory differed statistically[6] when amount versus accuracy was considered. However, when this memory measure was examined, it did emerge as a significant moderator of the relation between stress and memory [F(1,175) = 0.29 , *p* = .59], and there was a significant amount of residual heterogeneity among effects

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[6] Of note, measures that captured strictly the amount of information reported by youth were much less common than measures that accounted for accuracy in our sample, contributing a total of 16 effect sizes from 6 different studies. Measures accounting for accuracy in some way contributed 161 effect sizes spanning 21 studies.

[$Q(175) = 1028.95$, $p < .001$]. The average correlation between stress and memory accuracy was small, negative, and non-significant [$r_z = -.01$, $t(18.29) = -0.39$, $p = .70$], as was the average correlation between stress and memory amount [$r_z = -.04$, $t(18.29) = -0.39$, $p = .70$]. The difference between these effect sizes was also non-significant [$b = -.03$, $t(2.36) = -0.84$, $p = .48$]. The similarity in findings provides further support for the initial decision to combine both outcomes in the overall analyses, as already reported, and to analyze the combined measure in the moderator analyses as well.

Stress type

As mentioned, two types of stress categories were created, one dichotomous and one trichotomous. When stress type was dichotomized into physiological measures versus other stress measures, the moderator was significant, [$F(1, 154) = 8.61$, $p = .004$], with a significant amount of residual heterogeneity among effect sizes [$Q(154) = 903.97$, $p < .001$]. Findings were trending in the hypothesized direction, namely that physiological measures of stress would be positively related to memory, while other measures would be non-significantly related. However, the findings were still quite small. That is, the average correlation between physiological measures of stress and memory was positive but did not differ significantly from zero [$b = .06$, $t(7.94) = 1.40$, $p = .20$], and the average correlation between all other measures of stress and memory was small, negative, and also non-significant [$r_z = -.04$, $t(18.19) = -1.32$, $p = .21$]. Further, the pairwise comparison between average correlations in each category was significant without RVE adjustments [$b = -.10$, $t(154) = -2.93$, $p = .004$], but the pairwise comparison was non-significant once RVE adjustments were applied [$b = -.10$, $t(3.61) = -1.98$, $p = .13$].

Next, a three-level stress categorization was created, which included the physiological measures, along with two other categories, (i.e., physiological, self-report, other-report). This model was also significant [$F(2, 153) = 4.83$, $p = .009$], with a significant amount of residual heterogeneity [$Q(153) = 903.57$, $p <.001$]. The magnitude of the average correlation between physiological measures of stress and memory remained as just reported, which was small, positive, and non-significant [$r_z = .06$, $t(7.54) = 1.24$, $p = .25$] . The average correlations for self-report measures of stress and memory [$r_z = -.06$, $t(9.65) = -1.57$, $p = .15$] and other-report measures of stress and memory [$r_z = -.02$, $t(14.05) = -0.68$, $p = .51$] were small, negative, and neither differed significantly from zero. Of note, the pairwise comparison between physiological and self-report conditions was significant without RVE adjustments [$b = -.12$, $t(153) = -3.04$, $p = .003$], and remained marginally significant with RVE adjustments [$b = -.12$, $t(3.79) = -2.39$, $p = .08$]. However, pairwise comparisons between physiological measures and other-report conditions [$b = .08$, $t(3.57) = 1.35$, $p = .26$], and self-report and other-report conditions [$b = -.04$, $t(4.82) = -0.83$, $p = .44$] were both non-significant.

Age

Although there may be some reasons to suspect that comparisons between age-related categories (e.g., children versus adolescents, see for example Quas et al., 2018) might yield differential trends, such was not possible in the present investigation given overlapping ages across studies and the way that age was typically reported. Thus, age was examined as a continuous moderator using the average age of each sample as a proxy for youth age. Age coded in this manner was not a significant moderator [$F\ (1, 175) = 0.42$, $p = .52$]. A significant amount of heterogeneity among effects remained [$Q(175 = 1026.81$, $p <.001$].

Study Type

In contrast to the original hypotheses, study type did not emerge as significant moderator [$F(1,175) = 0.51$, $p = .47$] and a significant amount of heterogeneity remained [$Q(175) = 1027.93$, $p < .001$]. Findings were trending in the expected direction, namely that the relation between stress and memory would be negative or non-significant for naturally occurring events, and positive for analogue stressors. However, the average correlation between stress and memory for naturally occurring stressors was small, negative, and did not differ significantly from zero [$r_z = -0.03$, $t(13.0) = -1.01$, $p = .33$], while the average correlation between stress and memory for lab-induced stressors was small, positive, and non-significant [$r_z = .01$, t(6.84 = 0.44, $p = .68$]. Finally, pairwise comparisons between stress and memory for naturally occurring vs. lab-induced stressors were non-significant [$b = .04$, $t(15.5) = 1.03$, $p = .32$].

Delay

Delay between the to-be-remembered event and the memory was examined across four categorical levels (although even doing so across broader levels, such as very short to moderate delays, that is, 1 month or less, to long delays, that is, over one month did not yield different results). Moderator analyses were nonsignificant [$F(3,173) = 0.31$, $p = .82$], and there was a significant amount of residual heterogeneity [$Q(173) = 1026.87$, $p < .001$]. Average correlations between stress and memory were small, negative, and non-significant for immediate [$r_z = -0.01$, $t(3.49) = -0.35$, $p = .75$], short [$r_z = -0.03$, $t(10.97) = -1.03$, $p = .33$], and extended [$r_z = -0.01$, $t(3.71) = -0.17$, $p = .87$] periods of delay. The average correlation was small, positive, and non-significant for moderate delays [$r_z = 0.08$, $t(1.00) = 0.69$, $p = .61$]. Finally, none of the pairwise comparisons between delay categories was significant: immediate vs. short [$b = -0.02$, $t(4.48) = -0.59$, $p = .58$], immediate vs. moderate [$b = 0.09$, $t(1.42) = 0.75$, $p = .57$], immediate vs. long, [b

= 0.00, $t(5.89) = -0.03$, $p = .97$], short vs. moderate [$b = .11$, $t(1.27) =$, $p = .50$], short vs. long [b =.02 , $t(5.37) = 0.21$, $p = .84$], and moderate vs. long. [$b = -.10$, $t(2.34) = -0.68$, $p = .56$].

Exploratory Moderators

In addition to the hypothesized moderators, exploratory moderators were considered based on the availability of specific methodological and demographic variables across studies in the sample. These included question type, suggestibility, proportion white, proportion female, and region.

Question type was divided into three categories: recall, recognition, or combined. The relation between stress and memory did not vary as a function of question type [$F(2,174)= 0.11$, $p = .90$]. A significant amount of heterogeneity among effects remained [$Q(175) = 1026.8144$, p <.001]. Average correlations between stress and recall memory outcomes were small, negative, and non-significant [$r_z = -0.02$, $t(15.86) = -0.76$, $p = .46$], as were average correlations between stress and memory outcomes involving both recall and recognition questions [$r_z = -0.02$, $t(12.66) = -0.46$, $p = .65$]. The average correlation between stress and recognition memory was nearly zero, and non-significant [$r_z = 0.00$, $t(3.63) = 0.13$, $p = .91$]. Finally, pairwise comparisons between these categories were all non-significant including recall vs. recognition [$b = 0.02$, $t(2.22) = 0.69$, $p = .55$], recall vs. both [$b = 0.00$, $t(4.43) = 0.03$, $p = .98$], and recognition vs. both [$b = -.02$, $t(4.38) = -0.45$, $p = .67$].

Another memory related moderator concerned whether the memory test included suggestive questioning. Moderator results indicated the relation between stress and memory did not vary as a function of suggestibility [$F(1,173) = .12$, $p = .73$], with a significant amount of residual heterogeneity among effect sizes remaining [$Q(173) = 1027.93$]. The relation between stress and memory measures with suggestive questions [r_z = -.02 , t(10.80) = -0.65, p = .53] and without suggestive questions [r_z = -.01 , t(18.45) = -0.44, p = .67] were both small, negative, and non-significant. Furthermore, the difference between these two correlations was also non-significant [b = .01 , t(4.54) = 0.47, p = .65].

When the proportion of female participants in each study was considered, the model was non-significant [F(1,127) = 1.04, p = .31], and there was a significant amount of heterogeneity remained [Q(127) = 759.00, p <.001]. Likewise, the proportion of White/Caucasian youth in each sample was also non-significant [F(1,113) = 0.70, p = .40], and a significant amount of heterogeneity remained [Q(1,113) = .70, p <.001]. And finally, the reported relations between stress and memory were compared between region (North America vs. other). The moderator was non-significant [F(1,175) = .03, p = .86], with a significant amount of residual heterogeneity [Q(175) = 1028.90, p <.001]. The relation between stress and memory was small, negative, and non-significant for studies conducted in North America [r_z = -0.02 , t(17.00) = -0.70, p = .50] and nearly zero and non-significant for studies conducted in other regions of the world [r_z = 0.00 , t(3.00) = -0.04, p = .97]. The difference in correlations between the two categories was also non-significant [b = 0.01 , t(4.70) = 0.19, p = .85].

Full model

Finally, the full model, which included all 11 moderators and 2 covariate variables was examined. The model was non-significant[F(15,55) = 1.06, p = .41], and a significant amount of residual heterogeneity remained [Q(55) = 319.04, p <.001]. Thus, even after accounting for all covariates, and the planned and exploratory moderators, a significant amount of unexplained variation remained among the correlations. Potential explanations for this residual heterogeneity are addressed in the Discussion.

Table 2 *Overall and Moderator Results for Stress and Memory Correlations*

	Stress and Memory r_z (k = 30, r_z = 177)			
Meta-analysis	r_z	SE	t(df)	p
Summary Correlation	-0.01	0.02	-0.61(20.6)	.55
Moderators				
Memory outcome	$F(1, 175) = 0.29, p = .59$			
accuracy	-0.01	0.02	-0.39(18.29)	.70
amount	-0.04	0.03	-1.24(3.16)	.30
Stress Type 1	$F(2, 153) = 4.83, p = .009$			
Self-report	-0.06	0.04	-1.57(9.65)	.15
Other-report	-0.02	0.03	-0.68(14.05)	.51
Physiological	0.06	0.05	1.24(7.54)	.25
Stress Type 2	$F(1, 154) = 8.61, p = .004$			
Physiological	0.06	0.05	1.40(7.94)	.20
Other	-0.04	0.03	-1.32(18.19)	.21
Age	$F(1, 175) = 0.42, p = .52$			
	-0.01	0.00	-1.30(6.25)	.24
Study Type	$F(1,175) = 0.51, p = .47$			
Naturally occurring	-0.03	0.03	-1.01(13.0)	.33
Lab-induced	0.01	0.03	0.44(6.84)	.68
Delay	$F(3,173) = 0.31, p = .82$			
A day or less	-0.01	0.03	-0.35(3.49)	.75
Less than two weeks	-0.03	0.03	-1.03(10.97)	.33
Less than a month	0.08	0.12	0.69(1.00)	.61
Over a month	-0.01	0.07	-0.17(3.71)	0.87
Question type	$F(2,174)= 0.11, p = .90$			
recall	-0.02	.02	-0.76(15.84)	.46
recognition	0.00	0.03	0.13(3.63)	.91
both	-.02	0.03	-0.46(12.66)	.65
Suggestibility	$F(1,173) = .12, p = .73$			
not present	-0.01	0.02	-0.44(18.45)	.67
present	-0.02	0.03	-0.65(10.80)	.53
Proportion Female	$F(1,127) = 1.04, p = .31$			
	0.00	0.00	1.25(8.07)	.25
Proportion White	$F(1,113) = 0.70, p = .40$			
	0.18	0.18	0.98(5.59)	.37
Region	$F(1,175) = .03, p = .86$			
North America	-.02	.02	-.70(17.0)	.50
Other	0.00	0.07	-0.04(3.0)	0.97
Publication status (c)	$F(1,175) = 0.11, p = .74$			
published	-.02	.03	-0.73(16.51)	0.48
unpublished	0.00	0.03	-0.03(3.60)	0.98
Publication Year (c)	$F(1,175) = 0.12\ p = .73$			
	0.00	0.00	0.50(11.4)	.63

Note: k = number of studies. The F-ratio and associated statistics indicate whether the moderator explains a significant proportion of the variation in effect sizes. For categorical moderators, estimates should be interpreted as the average correlation for each group. For continuous moderators estimates should be interpreted as how the correlation between stress and memory changes with a one-unit increase in said variable. T-scores, degrees of freedom (df), and p-values are adjusted based on robust variance estimation. Model statistics and p-values are for models and estimates unadjusted by covariates. Positive correlations indicate that an increase in stress is associated with better memory.

DISCUSSION

The present investigation represents the first comprehensive attempt to synthesize findings concerning how stress during a to-be-remembered event is related to the amount and accuracy of children's and adolescents' memory of that event. Important decisions are often based on youth's memory reports across forensic interviewing, social work, clinical, and other settings (Goodman & Melinder, 2013; Sprague et al., 2018; Quas & Lyon, 2019). Thus, understanding how youth's stress during an event relates to (and in some cases, impacts) memory for that event is critical. The current meta-analysis provided necessary and important insight relevant to that understanding.

Despite a seemingly large literature investigating links between stress and memory in youth, only 28 studies were ultimately included in this meta-analysis. This final sample was limited by how each study was designed, the need for appropriate indicators of stress and memory, and most importantly, availability of necessary data. When findings in studies were combined and examined in an overarching direct manner, no significant relation emerged in either direction. Thus, stress was not significantly related to how well children remembered or could answer questions about a prior salient stressful experience. Yet, studies varied in important ways, including the age range of the youth, the type of stressful event about which youth were questioned, and how stress and memory were measured. This variability was systematically evaluated to the extent possible to determine whether underlying patterns of associations between stress and youth's memory could be detected. Across all planned and exploratory moderators, "stress type" (i.e., the ways in which stress was measured) was the only significant moderator. The remaining moderators did not emerge as significant, nor did the full model including all moderators. Next, these findings are discussed in more detail, with an eye toward first why such a sizeable amount of unexplained variation remained in the full model and second, why stress type might be an important characteristic in relation to the role that stress plays in shaping memory. Finally, limitations of the current study and implications of the findings are reviewed, and recommendations regarding the next steps in continuing to unpack the relation between stress and memory across development are provided.

Weak Associations and Unexplained Variation

As a starting point, it is crucial to note that results point to little consistency in the relation between stress and memory across qualifying studies. The overall relation between stress and memory as mentioned was nearly zero, and only one moderator (stress type) emerged as significant. Some may interpret a non-significant average correlation and very few significant moderators as evidence that stress and memory are not related. However, according to the 95% prediction interval, correlations between stress and memory across qualifying studies fell in quite a wide (non-zero) range, with upper and lower bounds nearly identical in magnitude, but opposite in direction [95% PI(-.32, .30)]. Thus, it is important to consider the significant amount of residual heterogeneity in the full model that, if properly addressed explained, may illuminate how stress and memory are differentially related across contexts.

One potential explanation for this residual heterogeneity, for instance, is this meta-analysis incorrectly assumed a linear relation between stress and memory. Most studies evaluating stress and memory in youth assume the relation is monotonic in nature, and therefore use correlations and regression coefficients to quantify the potential association. However, it is possible that stress enhances memory up until a certain peak or "sweet spot" and then gradually negatively impacts memory (Deffenbacher et al., 2004). Despite studies mentioning the possibility of inverted-U relations, only two of the qualifying studies attempted to empirically test for these curvilinear relations (Bahrick et al., 1998; Peterson, 2010). Bahrick et al. (1998) reported that the amount recalled by youth followed an inverted-U shaped pattern, with youth whose homes were moderately damaged by Hurricane Andrew reporting greater amounts of detail than did youth whose homes were minimally or severely damaged. Peterson (2010), in contrast, found no evidence for an inverted-U relation between youth's memory for accidents that led to emergency room visits and their parent's reports on how stressed they were during the accident. Because so few studies tested for curvilinear relations, it was not possible to combine findings via meta-analysis and test for such relations. If the true relation is curvilinear, and if, of course, the full inverted-U spectrum of stressful experiences was equally included among the qualifying studies, the resulting meta-analytic test would yield an average correlation of zero.

Another possibility is that stress and memory *are* linearly related, but only when specific moderators are considered. It is possible the current investigation did not identify or test those specific moderators. Some may not have been measured and reported consistently enough to be included (e.g., personality), or perhaps the correct moderators were not identified. One important example of this concerns youth age. The way age-related data were reported precluded this meta-analysis from comparing distinct age groups as a moderator (e.g., children vs. adolescents). Many age ranges in our sample overlapped across childhood and adolescence (e.g., 3-13, 6-12, 7-14) and some even spanned the entirety of qualifying ages for this study (e.g., Chen, 2000). Thus, age could not be tested age as a categorical moderator. Instead, age was evaluated as a continuous moderator, using the average age of each sample. In many instances, this average likely masked differences between youth at either end of the age range. Therefore, in subsequent work, it will be of interest to evaluate how stress and memory are related at key points in development.

An additional moderator that may lack sufficient measurement nuance was event type. A few studies in the sample included both “low stress” and “high stress” conditions (Bahrick et al., 1998; Quas et al., 2014), but these categorizations of stress may not be universal across studies. For example, the highest levels of stress youth experience during an analogue laboratory activity may be similar to the lowest levels of stress youth experience during an invasive medical procedure. Some attempt was made to test for this possibility in the “study type” (naturalistic vs. analogue) moderator analyses. However, no differences emerged. Further, even within analogue studies, high and low stress levels are still unlikely to be comparable across studies, for instance, when comparing memory for giving a distressing speech to watching a brief fearful video (Klemfuss et al., 2013; Quas & Lench, 2007). Unfortunately, more fine-grained comparisons of variations in type of event (e.g., TSST vs. VCUG vs. dental procedures), which could account for some of the residual heterogeneity in the model, were not possible.

Finally, as mentioned, many potentially important moderators were not available for inclusion in the full model as they were very seldom considered or reported in qualifying studies. They include memory information type (central vs. peripheral), specific emotion type (fear, upset, anger, sadness), and interview context (supportive vs. not).

One main mechanism through which stress impacts memory is via attention (Christianson, 1992; Chun & Turk-Browne, 2007), and memory narrowing models posit that stress enhances memory for details related to the cause of the stress and inhibit memory for unrelated details (Christianson, 1992; Levine et al., 2009; Reisber & Hertel, 2003). Only a few studies in the current sample distinguished between central and peripheral details in the memory outcome data (Patel, 1997; Rush et al., 2011; Vandermaas et al., 1993). In the original studies, authors reported some support for memory narrowing. For example, Rush et al. (2011) found that greater lab induced stress resulted in decreased correct responses to questions about peripheral relative to central details for both youth and adults in their sample. Furthermore, studies involving both children and adults that did not qualify for this meta-analysis have provided additional support for memory narrowing theories. For example, Peterson and Whalen (2001) interviewed children about an injury and found they were more accurate about central details of their experience than peripheral details. Finally, Christianson and Hubinette (2003) found that witnesses of a robbery were more accurate in identifying central details of a crime than peripheral details. Thus, the inability to distinguish these memory outcomes may be an additional source of residual heterogeneity.

The effects of stress on memory may also vary as a function of the discrete emotion (fear vs. anger, for example) that is activated during a stressful encounter. Motivational theories of emotion argue that discrete emotions drive attention in and memory in unique ways (Kaplan et al., 2012; Levine & Edelstein, 2009). For example, across two studies, Levine et al. (2008) had children read a story and then undergo an emotion manipulation, in which they either experienced happiness, anger, or sadness. Young children were more susceptible to misleading memory questions about the story when they experienced sadness than when they experienced anger. Although events in the present study certainly induced a variety of discrete emotions, these were very seldom measured and reported. Thus, it is possible that the impacts of specific emotions on memory were masked by the categorization of all negative emotions as "stress."

Finally, in other research on children's eyewitness memory, interview context (e.g., whether it is supportive or not) has emerged as an important predictor of children's disclosures of trauma, as well as the accuracy of their reports of both stressful and non-stressful events (Almerigogna et al., 2007; Benia et al., 2015; Lavoie et al., 2021). Most studies that included what one would consider stressful events, though, did not meet the eligibility criteria for inclusion here. The studies often examined children's disclosures of abuse, typically a dichotomous outcome (which does not reflect either accuracy or completeness) and did not contain measures of stress (Hershkowitz, Horowitz, & Lamb, 2005; Orbach et al., 2000). Supportive contexts may indeed be especially important when youth are recounting stressful experiences, however, only a small number of studies in the current sample provided detailed information on how youth were interviewed (Klemfuss et al., 2013; Quas et al., 2019), again precluding statistical analyses of support effects. Thus, there are reasons to believe these, or other untested moderators may well account for variation in the relation between stress and memory observed in this meta-analysis.

Stress type as a significant moderator

A particularly interesting finding from the meta-analysis was that stress type emerged as a significant moderator. At the broadest level, the average correlation between physiological measures of stress and youth memory differed significantly from all other non-physiological measures included in the studies. Measures of physiological stress were weak and positively correlated to memory whereas other measures were weak and negatively correlated to memory. However, these correlations were not significantly different from one another in the RVE adjusted model nor did either of them reach significance in relation to zero.

When the other category of stress measures was revised, and two other categories were created, one reflecting self-report measures of stress and the other including other-report measures, analyses suggested that the differences between physiological and non-physiological measures were primarily driven by differences between physiological and self-report categories; physiological measures of stress were more positively related to memory than self-report measures of stress at a marginally significant level in the RVE adjusted model. Thus, hypotheses were partially supported, with the theoretically more objective (physiological) measures of stress trending positively with memory and subjective or at least more easily manipulated or biased (self-report/other report) measures of stress trending towards non-significant or negative relations.

Despite the marginally significantly findings, it is important to note that neither of the average correlations in each category differed significantly from zero. However, for the purpose of this meta-analysis, the physiological measures across qualifying reports were combined, despite these spanning a wide range of indices (i.e., heart rate, cortisol reactivity, blood pressure, and vagal tone) that tap different underlying regulatory systems. For instance, pre-ejection period, is a cardiac measure reflective of changes in activation of the flight-or-flight sympathetic nervous system, whereas cortisol, which in other studies was collected (e.g., Chen et al., 2000; Quas et al., 2012; Quas et al., 2019), indexes changes in activation of the hypothalamic pituitary adrenal axis, a separate and at times regulatory system that may operate in a coordinated manner to control arousal (McEwin, 2007; McEwen & Seeman, 2006). Finally, changes in heart rate, which have also been included in some studies (e.g., Lee, 2012) may be driven by activation of the sympathetic nervous system or withdrawal of the parasympathetic nervous systems, both branches of the autonomic nervous system that serve very different response and regulatory functions and may direct attention in distinct ways (Lane et al., 2009; Phan et al., 2002). Collapsing measures that are reflective of markedly different underlying biological systems that serve different functions in terms of action and regulation, likely makes it difficult to detect unidirectional effects of physiological arousal on memory, especially in youth. Indeed, Quas and Klemfuss (2014) laid out possible differential effects in a review on physiological stress responses and memory in youth, arguing that "parasympathetic withdrawal at encoding has been negatively associated with or not significantly related to memory, whereas sympathetic and hypothalamic–pituitary–adrenal axis activation has often been positively associated with or not related to memory" (p. 698). To capture such trends, it would be necessary to separate the different indicators and examine their independent and possibly interactive effects (e.g., Lee 2012; Quas et al., 2006). Unfortunately, there was not a sufficient number of physiological measures of the different systems across the qualifying studies to test for relations between activation of the different systems and memory. Such highlights another potential contribution to the significant residual heterogeneity in the full model and an area ripe for future exploration for scholars interested in how specific forms of physiological activation during an event impacts or relates to youth's subsequent memory.

Exploratory Moderators and Youth Memory

Beyond stress type, a number of other exploratory moderators were tested, but only in broad ways. Among these, those that did not emerge were question type, suggestibility, proportion female, proportion white, and the region in which the study took place. Although no a priori predictions were made for question type and suggestibility, it was somewhat surprising that important methodological choices regarding these memory measures did not explain a significant amount of variation among effect sizes across studies given that divergent findings have been reported in the literature. For example, Chae et al. (2018) found a positive association between stress and recognition memory but found no association between stress and memory in free recall. Quas et al. (2014) found that stress was negatively related to correct responses to recognition questions, but positively related to correct responses to misleading questions and unrelated to open-ended responses to recall prompts. Yet, questions ask for a wide range of types of information. Thus, perhaps question type matters far less than the content about which the questions are asking. For example, recognition and misleading questions might vary in whether they ask about actions or not, or central versus peripheral details. Youth's responses could be affected by stress, leading to higher-order interactions and much more nuanced trends, possibilities in need of continued explorations.

Other Limitations

Beyond the inability to consider a non-linear relation between stress and memory and limited moderator information in the available data, other limitations deserve mention. First, over half of the studies that met the qualification criteria did not have data that were in usable format, limiting our final sample (see Appendix E). Many of these studies were over 20 years old, and even though attempts were made to contact authors and collect needed data, very little additional information was recovered. It was most often the case that the authors no longer had access to the data, and, without information in the original study on effect size, the data could not be included. However, a careful read of the original studies suggested that a common reason why the authors did not report specific effect sizes was that the relations were nonsignificant. For instance, in an investigation of stress and memory for a medical examination, Baker-Ward and colleagues (1993) had parents, doctors, and nurse rate the youth's stress during the exam. The researchers summarized their findings as follows, "these assessments of children's stress were not associated with total recall performance at either the initial or delayed interviews" (p. 1529). Thus, it is not clear that the inclusion of data from a larger sample would have necessarily led to differences in the average correlation between stress and memory, although perhaps their inclusion would have enabled detection of moderator effects, or perhaps would have allowed for a larger number of moderators to be included.

A second limitation was the inability to distinguish among indicators of amount and accuracy. Although a handful of effect sizes strictly reflected how much youth were saying about the stressful event (amount), most were indicative of a combination of amount and accuracy considerations reflected in a variety of disparate measures (e.g., Brown et al., 1999; Chen et al., 2000). Thus, it was not possible to evaluate whether stress was differentially related to distinct memory outcomes such as the how much information youth provided regardless of accuracy (amount), the proportion of key details reported (completeness), and the proportion of correct information provided (overall accuracy).

This leads to a third, and related limitation; the current meta-analysis did not directly considered how stress is related to memory *errors* or suggestibility. Although some researchers explicitly reported that only accuracy measures were included because these were strongly negatively related to errors (Salmon 2002; Quas et al., 2007), correct and incorrect responses often were not the inverse of one another, for instance, because children instead said, "I don't know" (e.g., Lee, 2012; McKinnon et al., 2017). Thus, results concerning how stress is related to amount and accuracy in this meta-analysis do not speak to how stress specifically relates to memory errors. To evaluate the relation between memory and errors and suggestibility specifically, a separate meta-analysis is necessary.

A fourth limitation is that this meta-analysis, like a majority of the final sample of studies, did not test for causal relations. That is, most studies did not experimentally manipulate stress and instead examined associations between individual differences in youth's stress responses during an event and their later memory of that event. Of note, three studies in the final sample did experimentally manipulate stress (Goodman et al., 1991a, Klemfuss et al., 2013; Quas et al., 2014), and each of these reported generally weak, inconsistent, or non-significant differences in memory between youth in the high and low stress groups (standard mean differences ranged between -0.52 and 0.12). However, the designs, samples, and even patterns of findings varied substantially, including across different question types, making it difficult to draw definitive conclusions. For instance, Goodman and colleagues (1991) included 18 children ages 3-7, who experienced venipuncture or a sticker on their arm, whereas Klemfuss et al. (2013) included 8-10 and 12-14 year olds who completed a speech and math task under high or low evaluative conditions. In in the future, a larger number of studies with children across wider age ranges needs to be conducted that involve rigorous and creative manipulations of stress levels to ascertain how these manipulations affect memory, and possibly related constructs like attention, encoding, and consolidation.

Conclusions

Interest in youth's abilities to accurately report on stressful and even traumatic events flourished in the late 1980's and early 1990's in the historical context of growing awareness of the persuasiveness of childhood sexual abuse (Finkelhor & Dzuiba-Leatherman, 1994). This awareness led to questions about whether and how well children can remember stressful and salient prior experiences like sexual abuse. At the same time, debate regarding repression and false memories for traumatic events was beginning to take center stage, and scientists and practitioners were attempting to document whether and how well early traumas could be remembered over time, and the conditions under which false memories of trauma, particularly that occurred in childhood, could be created (Loftus & Ketcham, 1996; Pezdek, 1996). This work attempted to answer important questions, such as, "Can youth accurately remember stressful events?" and "How do youth's individual stress levels during an event impact the quality of their memory?". Thirty years later, hundreds of studies, often with divergent findings and interpretations, have been published in an effort to answer these questions (See Quas & Fivush, 2009 for a review).

This meta-analysis synthesized findings from a specific subset of these studies focused on how stress during a to-be-remembered salient experiences relates to youth's memory of that experience, that is, the question, "How does stress relate to memory in childhood and adolescence?" One clear answer, even if perhaps quite simplistic, is "It varies." Overall correlations between stress and memory, even in moderation models, were largely weak and non-significant. However, this meta-analysis also revealed that *how* stress is operationalized and measured across studies may well impact the relation between stress and youth's memory. Insofar as researchers desire to continue to unpack how stress impacts or relates to youth's memory in specific contexts, researchers should closely consider how they operationalize stress, and perhaps employ multiple stress measures in their design. Yet, researchers also need to expand their investigations to measure (and then report results on) a wide range of moderators. It is through these investigations, and with complete and detailed reporting on findings, that further meta-analyses will be able to be pursued, in the hopes of answering refined questions about the nature of the relation between stress and memory.

In closing, the role that acute stress plays in shaping episodic memory across development appears to be complex and highly influenced by context. It may be that the more consistently researchers are able to operationalize stress, memory, and moderators of the relation within a consistent age group and across similar contexts, the better chance they have at identifying patterns across studies. However, ecologically valid stress and memory research is both time and resource intensive. Therefore, as researchers continue to explore this relation, it is imperative for them to consider how their methodological decisions will impact the applications and limitations of their work in an applied context. These considerations will move the field forward, providing clear and convincing answers to questions relevant to stress, memory, and development.

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Yim, I. S., Quas, J. A., Rush, E. B., Granger, D. A., & Skoluda, N. (2015). Experimental manipulation of the Trier Social Stress Test-Modified (TSST-M) to vary arousal across development. *Psychoneuroendocrinology*, *57*, 61-71. https://doi.org/10.1016/j.psyneuen.2015.03.021

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*, 459-482.

Zimmer-Gembeck, M. J., & Skinner, E. A. (2011). Review: The development of coping across childhood and adolescence: An integrative review and critique of research. *International Journal of Behavioral Development*, *35*(1), 1 -17. https://doi.org/10.1177/0165025410384923

APPENDIX A

Abstract Screening Tool

For all questions below, answer “yes”, “no”, or “maybe/unsure”.

Any question answered “no” is excluded.

Do not answer any further questions after the first “no”.

1) Is the population unknown/children or adolescents? (college students are NOT youth)
    a) Could there be participants in sample between the age of 3 and 17?

2) Is there a potential quantitative measure of memory[7] of an event or experience?
    a) Specifically, could there be a report on the total amount recalled, or the overall accuracy of memory report?

3) Is there a potential quantitative measure, manipulation, or categorization (e.g., high vs. low) of youth’s stress, emotion, mood, or arousal[8] at the time the stressful, to-be-remembered event occurred?

4) Is there a typical population included in the sample?

5) If a clinical sample, is there a comparison/control group?

6) If the article is a review or meta-analysis, could there be an article cited that meets any of the above criteria?

[7] This excludes measures of working memory.

[8] Measures of stress or emotion in reaction to the event, such as PTSD symptoms, and measures of chronic stress and/or adversity history do not qualify for this study.

APPENDIX B

Full Text Screening Tool

1. Are there participants between 3 and 17 years of age BOTH:
    a. During the TBR event?
    b. When is the memory assessed?

2. Is it an actual study that contains data, more than just a single case?

3. Is there an objectively stressful or unpleasant to be remembered (TBR) event unfolding over time[9] that the youth directly participated in or witnessed?

4. Is there a quantitative measure *or* manipulation of participant stress, emotion, mood, or arousal during the TBR event? [10]

5. Is there a quantitative measure of memory for more than one detail of a TBR event or experience that in some way assesses the total amount of information recalled, and/or the accuracy of information reported by the youth?

6. Is the original event documented or confirmed in some way?
    a. Did the event take place in the lab? *or*
    b. Is there a medical record, parental confirmation, court documents, or other verifiable external confirmation that the general event occurred? [11](e.g. weather report for the occurrence of a hurricane)

7. Is there a normal population?
    a. If a clinically diagnosed disorder or brain injury is being studied, does the sample include a non-clinical control group?

8. Was the memory free from the following influences?
    a. Repeated testing
    b. Anesthesia during memory consolidation

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[9] Negatively valanced stimuli such as words and photos do not qualify. The TBR must be a dynamic witnessed or experienced event.

[10] Number of events does NOT count as a quantitative measure of stress/arousal (e.g., total instances of abuse).

[11] Details of the event do not need to be documented, there simply needs to be confirmation that the event the youth is being asked about and reporting on did indeed occur. Instances in which youth are asked about an unconfirmed negative experience do not qualify.

c. Intentional memory interference between the event and the memory test
d. Parental reminiscing
9. Was the full text available in English?

APPENDIX C

Coding Protocol

Report Characteristics

1. What is the report ID number? (ID)

2. What are the first three authors' last names: X, Y, Z? (AUTHORS)

3. What was the year of appearance of the report or publication? (YEAR)

4. What type of report is this? (PUBTYPE)

   Journal article

   Book chapter

   Dissertation

   Masters thesis

   Private report

   Government Report

   Conference Paper

   Other (specify)

5. What is the status of the report? (PUBSTATUS)

   Published

   Unpublished

Setting Characteristics

6. In what country was the study conducted? (COUNTRY)

7. From what setting were participants recruited? (SETTING)

   Clinical/Medical
   Community
   Other (specify)

Participant Characteristics

8. What is the overall sample size? (N)

9. What percentage of the sample was female? (PROP_FEMALE)

10. What as the average age of the sample? (AGE)

11. What was the age range in the sample? (AGE_RANGE)

12. What proportion of the sample was Caucasian/white? (PROP_WHITE)

13. What was the specific racial breakdown of the sample? (RACE)

Stress

14. What is the author's label of the stress variable (STR_NAME)

15. Is stress a continuous variable for this effect size? (STR_CONT)

    Yes
    No

16. How was stress measured? (STR_TYPE)

    Physiological
    Observational/Behavioral
    Self-report
    Other-report
    Environmental Indicators
    Other (specify_______________________________)

17. If applicable, what is the name and citation of the stress measure? (STR_MEAS_CITE)

18. Was the stress measure created or adapted for this study? (STR_MEAS_ORIGIN)

    Created
    Adapted
    Neither (original measure cited above)

19. If created or adapted, specify how (STR_MEAS_HOW)

20. Was evidence presented for the reliability of this measure? (STR_RELIABILITY)

Yes
No

21. If yes, provide the type of reliability coefficient (STR_COEFF_TYPE)

22. If yes, provide the reliability value in decimals (STR_COEFF_VALUE)

23. When was the stress measure taken? (STR_TIMING)

During the TBR event
Retrospectively

24. Was stress experimentally manipulated? (STR_MAN)

Yes
No

25. How was stress manipulated? (STR_MAN_DESC)

26. What is the name and citation of the stress manipulation? (STR_MAN_NAME)

27. Was the manipulation created or adapted for this study? (STR_MAN_ORIGIN)

Created
Adapted
Neither (original manipulation cited above)

28. If created or adapted, specify how (STR_MAN_HOW)

29. Was evidence presented that the manipulation was successful?) (STR_MAN_CHECK)

Yes
No

30. Did this study place participants in low and high stress groups? (STR_GROUPS)

Yes

No

31. What was the name of the low stress group? (STR_LOW_NAME)

32. What is the name of the high stress group? (STR_HIGH_NAME)

Memory

33. Provide the authors label of the memory outcome (MEM_NAME)
34. What kind of prompt was used to elicit youth's memory for the event? (QUESTION_TYPE)

    Free recall

    Cued recall/direct questions

    Forced choice

    Multiple question types were employed (specify)

    Other (specify)

35. What category does this outcome fall under? (MEM_TYPE1)

    Accuracy

    Amount

36. What category does this outcome fall under? (MEM_TYPE1)

    Sum/total

    Proportion/percentage

37. Did the prompt include mislead questions?

    Yes, all of the questions were misleading

    Yes, some of the questions were misleading

    No

    Did not specify

38. How was the memory measure developed? (MEM_MEAS_HOW)
39. Was evidence presented for the reliability of this measure? (MEM_RELIABILITY)

    Yes

    No

40. If yes, provide the type of reliability coefficient (MEM_COEFF_TYPE)

41. If yes, provide the reliability value in decimals (MEM_COEFF_VALUE)

Moderator information

42. Is this effect size a sub-analysis of the entire sample? (SUB_ANALYSIS)

    Yes

    No

43. If yes, what subgroup does the effect size you are reporting belong to?

    (SUB_ANALYSIS_DESCRIBE)

44. If yes, how many participants are in this subgroup? (SUBGROUP_N)

45. Did the stressful event take place naturally or was it induced in the lab? (EVENT_TYPE)

    Naturalistic

    Analogue

46. What specific stressful event(s) did the youth witness or experience?

    (EVENT_SPECIFY)

47. Was the stressful event experienced or observed by the youth (POV)

    Experienced

    Observed

48. What was the average delay between the event and the memory test? (DELAY)

49. What was the range of delays between the event and the memory test?

    (DELAY_RANGE)

50. Was the memory interview supportive or non-supportive? (INTERVIEW_TYPE)

    Non-supportive

    Supportive

    Did not specify

51. Did this memory outcome include central or peripheral details? (INFO_TYPE)

Central

Peripheral

Both/Did not specify

52. Did this report specify what negative emotion was induced or measured? If so, specify (EMOTION)

53. Is this sample at-risk? (RISK)

Yes

No

Effect Size

54. What is the effect size index as labeled by the authors? (ES_INDEX)

Cohen's d

Hedge's g

Pearson's r

Partial correlation

Spearman's correlation

Other (specify)

55. Provide the following information for the low stress group
    a. Sample size (N_LS)
    b. Mean of memory outcome (M_LS)
    c. SD (SD_LS)

56. Provide the following information for the high stress group
    a. Sample size (N_HS)
    b. Mean of memory outcome (M_HS)

c. SD (SD_HS)

57. What is the Cohen's d (high – low)? (COHENS_D)

58. What is the variance of Cohen's *d*? (SD_COHENS_D)

59. How did you calculate this effect size? (CALC_METHOD)

60. If provided, what is the correlation coefficient between the stress and memory variables in this row? (R)

61. How man participants were used to calculate this correlation? (R_N)

62. What page was the effect size information found on? (PAGE)

63. If an effect size was not reported, what inferential information was provided? (INF_DESCRIBE)

64. Provide the specific inferential statistics here (INF_LIST)

Other

65. Do we need to email the authors? (EMAIL)

    Yes
    No

66. If we need to email the authors, what information do we need? (EMAIL_INFO)

67. Any important notes? (NOTES)

APPENDIX D

Final Sample Characteristics

Study	N	Mean age	Age range	Stress type(s)	Study/Event Type	Delay category
Alexander et al. 2002	51	5.30	3-7	other-report	naturalistic: inoculations	Two weeks or less
Bahrick et al. 1998[a]	100	4.35	3-4	other-report	naturalistic: Hurricane Andrew	Over a month
Baker□Ward et al. 2015	28	8.49	4-11	other-report	naturalistic: minor operative dental procedure	One day or less
Baugerud & Melinder, 2012[b]	37	8.38	3-12	other-report	naturalistic: CPS removal	Two weeks or less
Bray et al., 2018	38	12.40	7-17	other-report	naturalistic: injury accident	Two weeks or less
Brown et al., 1999	20	4.11	3-5	other-report	naturalistic: Pediatric Assessment vs. VCUG	Two weeks or less
Chae et al., 2014	91	4.52	3-6	other-report	naturalistic: inoculations	Two weeks or less
Chae et al., 2018	88	4.08	3-5	other-report	analogue: modified strange situation	One month or less
Chen et al., 1999[c]	*Same sample as Chen et al. 2000. No unique effect size data reported or considered.					
Chen et al., 2000[c]	55	7.10	3-17	self report, other-report, physiological	naturalistic: lumbar punctures	Two weeks or less

Goodman et al., 1991	18	4.96	3-7	low vs. high stress groups	naturalistic: fake tattoos vs. venipunctures	Two weeks or less
Imhoff, 2000	56	3.50	3-4	self-report	analogue: fire alarm	One day or less
Klemfuss et al., 2013	169	10.21	7-12	low vs. high stress groups	analogue: TSST-M	Two weeks or less
Lee, 2012_1	63	6.94	4-10	other-report	naturalistic: dental procedure	One day or less
Lee, 2012_2	85	6.94	4-12	self report, other-report, physiological	naturalistic: dental procedure	One day or less
McKinnon et al., 2017_1	36	10.41	7-16	self-report	naturalistic: k-wire removal	Two weeks or less
McKinnon et al., 2017_2	56	11.81	7-16	self-report	naturalistic: accidental injuries	Two weeks or less
Melinder et al., 2013[b]	28	7.96	3-12	other-report	naturalistic: CPS removal	Two weeks or less
Patel, 1997	50	5.00	4-5	self-report, other-report	naturalistic: inoculations	One day or less
Peterson, 2010	145	5.90	2-13	self-report	naturalistic: injury, emergency room visit	Two weeks or less
Quas & Dickerson, 2019	98	11.56	8-14	physiological	analogue: TSST-M	Two weeks or less
Quas, & Lench, 2007	109	6.09	5-6	physiological	analogue: fear eliciting video	Two weeks or less
Quas et al., 2006	106	6.30	4-8	physiological	analogue: fire alarm	One day or less
Quas et al., 2011	28	10.68	9-12	self-report	analogue: TSST-M	Two weeks or less

Quas et al., 2012[d]	65	7.55	7-14	physiological	analogue: TSST-M	
Quas et al., 2014	168	10.23	7-14	self report, other-report, physiological, low vs. high stress groups	analogue: TSST-M	Two weeks or less
Rush et al., 2011[d]	*Subsample of Quas et al. 2012. No unique effect size data reported or considered.					
Sales et al., 2005[a]	35	4.25	3-4	self-report, other-report	naturalistic: Hurricane Andrew	Over one month
Salmon, Price, & Pereira, 2002	32	3.79	2-7	other-report	naturalistic: VCUG	Over one month
Switzer, 2005	108	5.06	3-5	other-report	naturalistic: inoculations	Over one month
Vandermaas, Hess, & Baker□Ward, 1993	80	4.76	4-8	stress groups	naturalistic: teeth cleaning vs. operative dental procedure	One day or less
Weilenman, 1998	39	3.46	3-4	other-report	naturalistic: teeth cleaning	Over one month

Note. N refers to the full sample recruited for the study—the number of participants used to calculate effect sizes in each study varied by correlation. Average ages are also based on the full sample. Descriptions of stress-type and event type correspond only to the available effect size information used in the current analysis. That is, some studies listed may have included more stress measures and/or events in their original study, but these were not reported here if the effect size information was not available for the purposes of this meta-analysis. Matching superscripts indicate that the studies had overlapping samples. In the study column, underscores followed by a number after the study year indicate that the report listed included more than one qualifying study.

APPENDIX E

Qualifying Studies without Available Data

The following studies qualified based on inclusion criteria, but were not included in the sample because the necessary data to calculate relevant effect sizes were unavailable.

Baker□Ward, L., Gordon, B. N., Ornstein, P. A., Larus, D. M., & Clubb, P. A. (1993). Young children's long□term retention of a pediatric examination. *Child Development, 64*(5), 1519-1533. https://doi.org/10.1111/j.1467-8624.1993.tb02968.x

Baugerud, G. A., Magnussen, S., & Melinder, A. (2014). High accuracy but low consistency in children's long-term recall of a real-life stressful event. *Journal of Experimental Child Psychology*, 126, 357-368. https://doi.org/10.1016/j.jecp.2014.05.009

Bugental, D. B., Blue, J., Cortez, V., Fleck, K., & Rodriguez, A. (1992). Influences of witnessed affect on information processing in children*.* *Child Development, 63*(4), 774-786. http://dx.doi.org/10.2307/1131232

Burgwyn-Bailes, E. (1999). Children's memory for a traumatic event after one year: An examination of individual differences and recall, suggestibility, and narrative consistency [Doctoral dissertation, University of North Carolina at Chapel Hill]. ProQuest Dissertations Publishing.

Burgwyn-Bailes, E., Baker-Ward, L., Gordon, B. N., & Ornstein, P. A. (2001). Children's memory for emergency medical treatment after one year: The impact of individual difference variables on recall and suggestibility. *Applied Cognitive Psychology, 15*(7), 25-48. http://dx.doi.org/10.1002/acp.833

Burstein, S., & Meichenbaum, D. (1979). The work of worrying in children undergoing surgery. Journal of *Abnormal Child Psychology, 7*(2), 121-132. http://dx.doi.org/10.1007/BF00918893

Davis, E. L., & Levine, L. J. (2013). Emotion regulation strategies that promote learning: Reappraisal enhances children's memory for educational information. *Child development, 84*(1), 361-374. https://doi.org/10.1111/j.1467-8624.2012.01836.x

Eisen, M. L., Qin, J., Goodman, G. S., & Davis, S. L. (2002). Memory and suggestibility in maltreated children: Age, stress arousal, dissociation, and psychopathology. *Journal of Experimental Child Psychology*, 83(3), 167-212. https://doi.org/10.1016/s0022-0965(02)00126-1

Eisen, M. L., Goodman, G. S., Qin, J., Davis, S., & Crayton, J. (2007). Maltreated children's memory: Accuracy, suggestibility, and psychopathology. *Developmental psychology, 43*(6), 1275. https://doi.org/10.1037/0012-1649.43.6.1275

Goodman, G. S., Bottoms, B. L., Schwartz-Kenney, B. M., & Rudy, L. (1991). Children's testimony about a stressful event: Improving children's reports. *Journal of Narrative and Life History, 1*(1), 69-99. https://doi.org/10.1075/jnlh.1.1.05chi

Goodman, G. S., Quas, J. A., Batterman-Faunce, J., Riddlesberger, M. M., & Kuhn, J. (1994). Predictors of accurate and inaccurate memories of traumatic events experienced in childhood. *Consciousness and Cognition: An International* Journal, 3(3), 269-294. http://dx.doi.org/10.1006/ccog.1994.1016

Goodman, G. S., Quas, J. A., Batterman-Faunce, J., Riddlesberger, M. M., & Kuhn, J. (1997). Children's reactions to and memory for a stressful event: Influences of age, anatomical dolls, knowledge, and parental attachment. *Applied Developmental Science, 1*(2), 54-75. http://dx.doi.org/10.1207/s1532480xads0102_1

Howe, M. L., Courage, M. L., & Peterson, C. (1994). How can I remember when "I" wasn't there: Long-term retention of traumatic experiences and emergence of the cognitive self. *Consciousness and Cognition: An International Journal, 3*(3-4), 327-355. http://dx.doi.org/10.1006/ccog.1994.1019

Howe, M. L., Courage, M. L., & Peterson, C. (1995). Intrusions in preschoolers' recall of traumatic childhood events. *Psychonomic Bulletin and Review, 2*, 130–134. https://doi.org/10.3758/bf03214419

Lindberg, M. A., Jones, S., Collard, L. M., & Thomas, S. W. (2001). Similarities and differences in eyewitness testimonies of children who directly versus vicariously experience stress. *The Journal of Genetic Psychology, 162*(3), 314-333. https://doi.org/10.1080/00221320109597486

Liwag, M. D., & Stein, N. L. (1995). Children′ s memory for emotional events: The importance of emotion-related retrieval cues. *Journal of Experimental Child Psychology, 60*(1), 2-31. https://doi.org/10.1006/jecp.1995.1029

McKinnon, A., Brewer, N., Cameron, K., & Nixon, R. D. V. (2017). The relationship between processing style, trauma memory processes, and the development of posttraumatic stress symptoms in children and adolescents. *Journal of Behavior Therapy and Experimental Psychiatry, 57*, 135-142. http://dx.doi.org/10.1016/j.jbtep.2017.04.004

Merritt, K. A., Ornstein, P. A., & Spicker, B. (1994). Children's memory for a salient medical procedure: Implications for testimony. *Pediatrics, 94*(1), 17-23. https://doi.org/10.1542/peds.94.1.17

Oates, K., & Shrimpton, S. (1991). Children's memories for stressful and non-stressful events. *Medicine, Science and the Law, 31*(1), 4-10. https://doi.org/10.1177/002580249103100102

Ornstein, P. A., Gordon, B. N., & Larus, D. M. (1992). Children's memory for a personally experienced event: Implications for testimony. *Applied Cognitive Psychology, 6*(1), 49-60. https://doi.org/10.1002/acp.2350060103

Osborn, D. K., & Endsley, R. C. (1971). Emotional reactions of young children to TV violence. *Child Development*, 321-331. https://doi.org/10.2307/1127086

Parsafar, P., & Davis, E. L. (2018). Intrapersonal emotion regulation processes influence what children remember about their emotional experiences. *Child Development*, http://dx.doi.org/10.1111/cdev.13070

Parsafar, P., & Davis, E. L. (2019). Divergent effects of instructed and reported emotion regulation strategies on children’s memory for emotional information. *Cognition and Emotion, 33*(8), 1726-1735. https://doi.org/10.1080/02699931.2019.1598937

Peterson, C., & Bell, M. (1996). Children's memory for traumatic injury. *Child development, 67*(6), 3045-3070. https://doi.org/10.1111/j.1467-8624.1996.tb01902.x

Peterson, C., & Parsons, T. Children's Long-Term Memory for Injury. *Psychological Bulletin, 112*, 284-309.

Quas, J. A., Goodman, G. S., Bidrose, S., Pipe, M., Craw, S., & Ablin, D. S. (1999). Emotion and memory: Children's long-term remembering, forgetting, and suggestibility. *Journal of Experimental Child Psychology, 72*(4), 235-270. http://dx.doi.org/10.1006/jecp.1999.2491

Quas, J. A., Bauer, A., & Boyce, W. T. (2004). Physiological reactivity, social support, and memory in early childhood. *Child Development, 75*(3), 797-814. https://doi.org/10.1111/j.1467-8624.2004.00707.x

Rocha, E. M. (2003). Children's memories of dental procedures: Effects of individual differences, question type and temporal delay. [Doctoral dissertation, , University of Saskatchewan, Saskatoon]. Government of Canada.

Salmon, K., McGuigan, F., & Pereira, J. K. (2006). Brief report: optimizing children’s memory and management of an invasive medical procedure: the influence of procedural narration and distraction. *Journal of Pediatric Psychology, 31*(5), 522-527. https://doi.org/10.1093/jpepsy/jsj081

Shrimpton, S., Oates, K., & Hayes, S. (1998). Children's memory of events: Effects of stress, age, time delay and location of interview. *Applied Cognitive Psychology, 12*(2), 133-143. http://dx.doi.org/10.1002/(SICI)1099-0720(199804)12:2<133::AID-ACP502>3.0.CO;2-E