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The Association Between Parent-to-Child Fear Learning Pathways and Anxiety Sensitivity: A Systematic Review and Meta-analysis

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Abstract

Although anxiety sensitivity (AS), or the fear of anxiety-related symptoms, has been identified as a risk factor for the development of anxiety psychopathology, the pathways through which this fear is learned have not been fully elucidated. In the current review and meta-analysis, we aimed to systematically examine the association between parent-to-child fear learning pathways (vicarious learning, negative information, reinforcement, and punishment) and AS. A comprehensive search of literature was conducted in PsychINFO, PubMed, Embase, and Web of Science databases, using search terms combining categories related to fear learning pathways, anxiety-related symptoms, parents, children, and adolescents. Based on this search strategy, 28 studies were identified as relevant, of which 11 were included in the systematic review and 10 in the meta-analysis. The overall findings indicated that parent-to-child fear learning pathways are significantly associated with AS. The meta-analysis demonstrated a small but significant association between fear learning pathways and AS, although the type of fear learning pathway did not significantly moderate this relationship. However, age emerged as a significant moderator, suggesting a stronger association in children and adolescents compared to adults. Given that these findings are primarily based on cross-sectional studies, this review underscores the need for longitudinal and experimental research to further clarify the role of parent-to-child fear learning pathways in anxiety sensitivity. Additionally, a better understanding of these pathways may help inform existing interventions and fear prevention strategies, such as those aimed at reducing parental modeling of fearful behaviors or promoting positive verbal messages about anxiety symptoms.

Keywords Fear · Anxiety sensitivity · Learning pathway · Systematic review · Meta-analysis

Everyone at some point might experience bodily symptoms such as heart palpitations, nausea, or abdominal pain. These commonly occurring symptoms can arise for a number of reasons, for example, due to changes in everyday routines, minor ailments, or in response to stressful life events (Asmundson & Taylor, 2005). However, the perception of these bodily symptoms varies greatly among individuals. While some individuals may perceive these symptoms as transient and benign, others may (mis)interpret such harmless bodily symptoms as threatening and indicative of a potentially serious physical harm (e.g., a serious illness, heart attack) or an upcoming panic attack. One trait-like, cognitive variable that might explain the individual difference in tendency to misinterpret and associate benign bodily symptoms with threat is known as anxiety sensitivity (AS) or the fear of anxiety-related symptoms (Reiss et al., 1986). This construct is distinct from other anxiety-related constructs, such as trait anxiety, which refers to a more general tendency to fear a wide range of stressors and across a variety of situations (McNally, 2002; Chorpita et al., 1996; Olatunji & Wolitzky-Taylor, 2009; Weems et al., 1997). In fact, AS is considered to be a dimensional construct, encompassing multiple dimensions of fear, including fear arising from belief that anxiety-related symptoms have harmful

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physical, social, and cognitive consequences (Rifkin et al., 2015; Taylor et al., 2007; Wheaton et al., 2012). To illustrate, heightened AS is characterized by an excessive fear in response to anxiety-related symptoms (e.g., racing heart, shortness of breath) due to the belief that these symptoms have harmful consequences (e.g., heart attack), whereas low AS lacks this distinctive characterization (Reiss, 1991).

AS is a particularly relevant construct considering that awareness of bodily symptoms and their association with emotions, such as fear and surprise, begin early in childhood. By around age 6, children develop an increasing ability to recognize and interpret bodily sensations (Hietanen et al., 2016; Muris et al., 2000a, 2004; Ollendick et al., 1996). Although some studies have questioned whether younger children can fully grasp the implications of bodily symptoms (Chorpita & Lilienfeld, 1999), evidence suggests that by age 7, children begin associating bodily symptoms with fear, interpreting sensations such as trembling hands, a fast heartbeat, and difficulty breathing as potentially threatening (Mattis & Ollendick, 1997; Muris et al., 2008, 2010b, 2000b; Weems et al., 1998, 2021). Notably, several studies have demonstrated that children and adolescents with heightened AS are at increased risk for developing anxiety-related psychopathology, including panic disorder, generalized anxiety disorder, social anxiety disorder, and separation anxiety (Joiner et al., 2002; Knapp et al., 2016; Kramer & Francis, 2025; Reiss et al., 2001; Weems et al., 1997, 2000; Wolitzky-Taylor et al., 2015). For example, one longitudinal study has shown that heightened AS at the age of 8 years was significantly associated with anxiety symptoms, especially somatic/panic symptoms, separation and generalized anxiety, and social phobia at the age of 10 years (Waszczuk et al., 2013). Similar results have been reported in adolescents, where heightened AS predicted the occurrence and worsening of anxiety symptoms and panic attacks over time, even after controlling for other variables, such as trait anxiety, negative affectivity, depression, and baseline anxiety (Allan et al., 2014; Deacon et al., 2002; Ginsburg & Drake, 2002; Hayward et al., 2000; Lau et al., 1996; Qi et al., 2019; Schmidt et al., 2010; van Widenfelt et al., 2002; Weems et al., 2002). Additionally, longitudinal research in non-Western samples has found similar results, showing that AS was predictive of both anxiety and depression symptoms 1 year later among Chinese adolescents in Hong Kong (Ho et al., 2018). Collectively, these studies suggest that elevated AS places children and adolescents at heightened risk for the development of anxiety-related psychopathology (Marin et al., 2008; Qi et al., 2019; Weems et al., 2010).

Considering that AS onsets early and predicts the development of anxiety symptoms and disorders (Ginsburg & Drake, 2002; Knapp et al., 2016; Marin et al., 2008; McLaughlin & Hatzenbuehler, 2009; Noël & Francis, 2011; Qi et al., 2019), it is crucial to understand its etiology. Theoretical models of AS have identified both genetic and environmental influences, with twin studies showing that while genetic factors contribute to AS, environmental influences account for a substantial proportion of the variance, either directly or through interactions with genetic predispositions (Eley et al., 2007; Hettema et al., 2020; Stein et al., 1999; Taylor et al., 2008; Zavos et al., 2012). Given the substantial role of environmental influences, extant research has increasingly focused on the family environment, where studies have consistently found that children of parents with heightened AS tend to have elevated AS levels themselves (Coppola et al., 2018; East et al., 2006; Francis & Noël, 2010; Graham & Weems, 2014; Ollendick & Horsch, 2007; Drake & Kearney, 2008; Tsao et al., 2005). Beyond the association between parent and child AS, a few studies have explored the role of specific parenting behaviors in relation to AS, reporting significant associations between childhood AS and negative parenting behaviors, such as threatening, hostile, rejecting, controlling behaviors, and corporal punishment (Erozkan, 2012; Gardner & Epkins, 2012; Graham & Weems, 2014; Gray et al., 2010; Nebbitt & Lambert, 2009; Scher & Stein, 2003). While these findings suggest that various parental behaviors may shape the environment that fosters AS, less is known about the specific ways in which children can learn to fear from their parents in the context of AS. Beyond these parenting behaviors, parents' own fearful responses to anxiety symptoms could also play a role in shaping children's AS. Thus, it is important to examine whether parental fearful behaviors are linked to children's and adolescents' fear of anxiety-related symptoms, and which fear learning pathways may be involved.

Theories of social learning and fear acquisition suggest that children can develop fears not only through direct aversive experiences but also through indirect learning experiences occurring within the family environment (e.g., by observing fearful parental behaviors) (Bandura & Walters, 1977; Rachman, 1977). Drawing on these theories, extensive research has demonstrated that children can learn to fear from their parents through three fear learning pathways: vicarious fear, negative information, and reinforcement or punishment (for a review, see Fisak & Grills-Taquechel, 2007; Ollendick & Muris, 2015; Ollendick & King, 1991; Muris & Field, 2010; Lebowitz et al., 2016; Aktar et al., 2017; Aktar & Pérez-Edgar, 2024). Through vicarious fear pathway, fears can be learned by observing fearful behaviors or fearful reactions in others. For example, research has shown that children who observe their parents displaying fearful facial expressions in response to various stimuli or situations, such as ambiguous toys, unfamiliar animals, or other potentially threatening stimuli (e.g., snakes, spiders, or strangers), subsequently exhibit heightened fear

responses to those same stimuli (Askew & Field, 2007; De Rosnay et al., 2006; Dunne & Askew, 2013; Gerull & Rapee, 2002; Marin et al., 2020; Murray et al., 2008). The second fear learning pathway involves learning fear through negative information, where children learn about potential dangers via verbal instructions or fear-relevant information from others (Muris & Field, 2010; for a review, see Percy et al., 2016). Research has shown that children who receive negative information from their parents about the threat posed by an unfamiliar stimulus, such as a novel toy or animal, are more likely to develop fear toward that stimulus (Field & Lawson, 2003; Field et al., 2001; Muris & Field, 2010; Muris et al., 2010a). The third fear learning pathway involves parental reinforcement and punishment, wherein parents' responses shape children's fear-related behaviors. Parents may inadvertently reinforce fear by providing rewards or special attention when a child expresses fear (positive reinforcement) or by facilitating avoidance of fear-provoking situations, such as allowing the child to stay home from school (negative reinforcement). Conversely, punishment or discouragement of fear expressions, such as criticism or disapproval, may heighten fear by teaching children that expressing fear is socially unacceptable or embarrassing (for a review, see Fisak & Grills-Taquechel, 2007; Öst & Hugdahl, 1981; Kirkby et al., 1995; King et al., 1998; Bilsky et al., 2018a).

Contemporary fear acquisition models suggest that these learning pathways operate through associative learning mechanisms that allow children to associate parents' fear behaviors (e.g., observing fearful facial expressions or hearing negative information) with potentially threatening stimuli or situations (e.g., ambiguous toys) (Aktar & Pérez-Edgar, 2024; Askew & Field, 2008; Field, 2006; Mineka & Cook, 1993; Mineka & Zinbarg, 2006). Although these models highlight the importance of learning pathways in the learning of fear, relatively fewer studies have examined how these pathways relate to AS. Several individual studies have suggested that vicarious learning, negative information, and reinforcement or punishment pathways may be linked to heightened AS (Ehlers, 1993; Watt et al., 1998), but the existing studies have varied in their methodologies and sample characteristics, making it difficult to draw conclusions about the overall strength and nature of these associations. Thus, a systematic review and meta-analysis would not only consolidate and critically evaluate the existing literature, but also provide a quantitative evaluation of the effects across those studies, offering a more precise estimate of the overall strength of the relationship between parent-to-child fear learning pathways and AS. Additionally, by systematically evaluating the literature, we would get a more comprehensive analysis of potential moderators that might influence the relationship between these learning pathways and AS. For example, as some previous studies have shown that females tend to report higher levels of AS in adult (Stewart et al., 1997) and child samples (Deacon et al., 2002; Muris et al., 2001; Stassart et al., 2014; van Widenfelt et al., 2002; Walsh et al., 2004), including sex as a moderator would allow us to investigate whether the relationship between fear learning pathways and AS differs in male as compared to female children and adolescents. Similarly, including age as a moderator is important, as the salience of specific learning pathways may vary across developmental stages (e.g., parental behaviors such as modeling might be particularly influential during childhood, while other pathways may be more prominent in adolescence) (for a review, see Allen et al., 2023; Leen-Feldner et al., 2006). Furthermore, considering ethnicity as a moderator is essential to account for potential cultural variations in the experience and expression of AS, as well as in the type of learning pathways that may be most salient. For example, cultural norms around emotion expression or parenting practices may influence the relationship of learning pathways and the AS (Cervantes, 2002; Essau et al., 2008, 2011; Graham & Weems, 2014; Ho et al., 2018; Varela et al., 2009).

The primary aim of the present review was to synthesize and combine the available evidence from studies investigating the relationship between parent-to-child fear learning pathways and AS. By doing so, this review aims to gain an in-depth understanding of how and which fear learning pathways may be associated with these fears, which, in turn, may help inform prevention programs and improve existing treatment strategies, for example, by targeting and preventing AS in at-risk children and adolescents (Bernstein & Zvolensky, 2007; Sherman et al., 2019).

Method

The present systematic review was designed and reported in accordance with the guidelines published in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021).

Search Strategy

To identify all the relevant articles, a systematic literature search was performed on December 4, 2023 using four electronic databases: PubMed, Web of Science, PsycINFO, and Embase. The search was limited to journal articles investigating past or present parent-to-child learning experiences in the context of anxiety-related symptoms. The literature search was restricted to publications in English language, with an unrestricted date of publication but limited up to the search date on December 4, 2023. The selection of the search terms in this systematic review was based on

the preliminary literature search and in consultation with references embedded in previously published reviews on the similar topic (e.g., Askew & Field, 2008; Fisak & Grills-Taquechel, 2007; Lebowitz et al., 2016; Nimphy et al., 2023). The first two authors (EA and JG) conducted the search by using the search terms for each database separately (see "Appendix A" for an overview of the search terms used).

Eligibility Criteria

The eligibility criteria for this systematic review were developed in accordance with the PICOS framework [(a) Population, (b) Intervention, (c) Comparison, (d) Outcome, (e) Study type] (Methley et al., 2014). To be included in the review, published articles needed to meet the following primary criteria: (a) having human child, adolescent, or adult participants (e.g., aged between 6 and 60 years), with no demographic restrictions, (b) addressing at least one fear learning pathway in the context of anxiety-related symptoms, (c) having no comparison criteria defined, (d) an outcome measure evaluating AS (i.e., Anxiety Sensitivity Index), and (e) having quantitative study design. The eligibility of each article was decided based on the title and abstract, including the full-text screening, where necessary (e.g., if the relevant information was missing from title and abstract).

Study Selection, Data Extraction, and Coding

We managed all studies using the Rayyan web management tool (Ouzzani et al., 2016). Studies were initially imported from PubMed (627 studies), Web of Science (761 studies), Embase (740 studies), and PsychInfo (688 studies) databases. Titles and abstracts of all studies were screened independently by the first two authors, including the selection and full-text extraction of all included studies based on the criteria described above.

Based on the full-text screening, the first two authors (EA, JG) extracted the following information from the included studies: title, first author, year, sociodemographic information (e.g., age, sex, ethnicity), clinical information (e.g., clinical diagnoses), methodological information (e.g., study location, study design, sample size, measures used for predictor and outcome variables), and statistical information of the variables of interest (e.g., means, standard deviations, correlation coefficients, *p*-values). To be included in the meta-analysis, the statistical information provided by each study had to be sufficient to allow for calculation of effect sizes for the variables of interest. The data were independently extracted and coded by the first and the second author (EA, JG). Overall, there was a 100% agreement between the two authors regarding the extraction of the data from the included studies. Categories were dummy coded for all discrete variables with two levels, including study design type (i.e., retrospective vs. current), sample age group (adults vs. children/adolescents), ethnicity group (homogeneous vs. mixed), and type of learning pathway (vicarious vs. verbal and instrumental).

Statistical Analyses

Statistical analyses were performed using the 'metafor' package in R statistical software (R Core Team, 2022; Viechtbauer, 2010). As most included studies yielded multiple effect sizes, we conducted a three-level meta-analysis, accounting for dependency of clustered effect sizes (Assink & Wibbelink, 2016; Harrer et al., 2021; Viechtbauer, 2010). Correlation coefficients between the fear learning pathways and AS were converted to z-scores using Fisher's *r*-to-*z* transformation for all analyses and then converted back into correlations using Fisher's *z*-to-*r* transformation (Borenstein, 2009; DeCoster, 2009). The overall effect was estimated based on the random effects model (Hedges & Vevea, 1998), and restricted maximum-likelihood estimator (REML, Viechtbauer, 2005) was used to calculate τ^2 at level 2 and level 3. Additionally, we used Cochran's *Q*-test and calculated the I^2-statistic to check for heterogeneity of effects (Cochran, 1954; Hedges & Olkin, 1985; Higgins & Thompson, 2002). Moderators of the overall effect were analyzed using meta-regressions directed by mixed-effects modeling (Hedges & Vevea, 1998).

Quality Assessment

The National Heart, Lung, and Blood Institute's Assessment Tool for Observational Cohort and Cross-Sectional Studies (National Heart, Lung, and Blood Institute, 2021) was used to assess the quality of all studies included in this review. The quality assessment tool consists of 14 items that check the internal validity of each study (see "Appendix B" for item descriptions). The first two authors (EA and JG) independently evaluated each of the included studies based on the 14 items, scoring "yes" if the criteria were fully met, "no" if the criteria were not met, or "other" if the criteria could not be determined, were not applied, or were not reported. Based on these scores, we calculated the overall quality rating for each study by summing up the number of items scoring "yes" for each study. Total score ranged from 0 to 14, with studies being assigned either poor, fair, or good rating. Studies obtaining less than 50% of the total score were assigned a poor rating, studies obtaining between 50 and 75% of the total score were assigned a fair quality rating, and studies obtaining above 75% of the total score were

assigned a good quality rating. If the overall quality rating of a study was either fair or good, this study was considered to have satisfactory internal validity and less risk of bias.

Results

The initial database search retrieved a total of 2816 articles, which the first author (EA) manually screened, identified, and deleted 1560 duplicate articles. After deleting the duplicates, in total 1256 articles were deemed eligible for title and abstract screening. The first two authors (EA, JG) independently screened titles and abstracts of 1256 unique article entries to check the fit with the eligibility criteria, with discrepancies resolved through discussion and consensus. Interrater reliability on the inclusion of studies based on their abstract and title was high, reaching Cohen's kappa index of 0.84 (McHugh, 2012). Based on the abstract and title screening, 1228 studies were excluded, leaving 28 studies eligible for full-text screening. After conducting the full-text screening, 17 studies were excluded (see Fig. 1 for exclusion reasons). Overall, 11 articles were included in the systematic review and 10 studies in the meta-analysis. Figure 1 illustrates the flowchart of the selection process resulting in the final number of included articles.

Quality Assessment

The studies included in this review were rated as having an overall good methodological quality, with most receiving a fair ($n = 7$; see "Appendix B," studies 1, 4, 6–10) or good

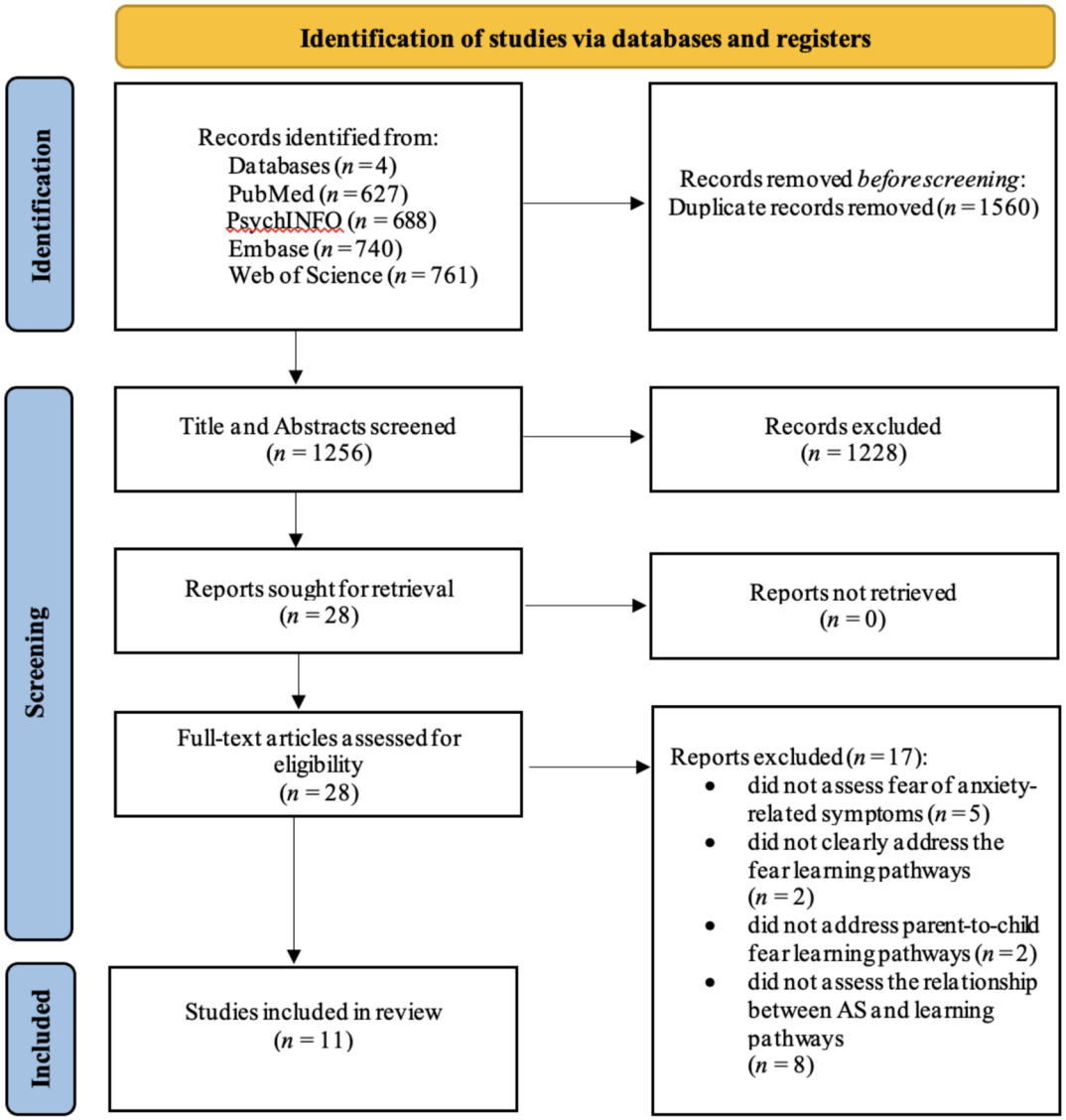

Fig. 1 PRISMA flowchart of the systematic search

($n = 4$; see "Appendix B," 2, 3, 5, 11) rating. Of the 7 studies rated as fair, 5 obtained 72% of the total score, indicating good internal validity despite the fair rating (see "Appendix B," studies 1, 4, 7, 9, 10). The included studies demonstrated methodological strength in their clearly stated research objectives, specified and defined population, and clearly defined, reliable exposure, and outcome measures. The most common methodological limitation in all included studies was due to the cross-sectional design (e.g., measurement of variables at one time point, and lack of follow-up assessment after the initial variables were measured). Another limitation was that none of the included studies provided a description of the power or a justification of the sample size. Only one study reported that 50% of eligible individuals participated, while most studies did not report participation rates (see "Appendix B," study 6).

Overview of the Included Studies

Study Design

Out of 11 included studies, all the studies had a cross-sectional design ($n = 11$; see "Appendix D," studies 1–11), with six studies utilizing a retrospective questionnaire to assess past learning experiences in adults ($n = 6$; see "Appendix D," studies 1–5, 11).

Location of Studies

The present systematic review included studies conducted primarily in the United States ($n = 4$; see "Appendix D," studies 5, 8, 9, 11) and Canada ($n = 4$; see "Appendix D," studies 1–4), with additional studies conducted in the Netherlands ($n = 2$; see "Appendix D," studies 6, 7) and Belgium ($n = 1$; see "Appendix D," study 10).

Sample Characteristics

The review included studies with sample sizes ranging from 52 to 543 participants, totaling 2297 participants across all included studies. Of these, 1632 were adults (947 females), 665 were children and adolescents (345 females). Six studies included adult participants, whereas five studies primarily consisted of child or adolescent samples. Of the 11 studies included, only one had a clinical sample ($n = 1$; see "Appendix D," study 9), while the remaining studies were primarily consisting of non-clinical samples ($n = 10$).

Measures

The assessment of the fear learning pathways was based on the Learning History Questionnaire (LHQ; Ehlers, 1993) or its modified versions (*LHQ-expanded version*, Watt et al., 1998; *LHQ-Revised*, Watt & Stewart, 2000; *LHQ-III*, Stewart et al., 2001; Leen-Feldner et al., 2008; Knapp et al., 2013; *LHQ-IV*, Watt et al., 2008; *LHQ-modified*, McGinn et al., 2015; *Parental socialization of anxious behaviors interview schedule (P-SABIS)*, Holly & Pina, 2015) across the included studies assessing childhood learning experiences in adults ($n = 6$; see "Appendix D," studies 1–5, 11). Two other studies have employed the Learning Experiences Interview (LEI), an adapted version of the LHQ, to evaluate childhood (present) learning experiences in children and adolescents (see "Appendix D," studies 6, 7), whereas one study has used Learning Experience Index-second version (LEI-II), which is an expanded version of LEI (Stassart et al., 2017; see "Appendix D," study 10).

For the assessment of fear of anxiety-related symptoms, six included studies used the Anxiety Sensitivity Index (ASI; Reiss et al., 1986) or its modified versions (ASI-Revised, Taylor & Cox, 1998; ASI-3, Taylor et al., 2007) in adult populations (see "Appendix D," studies 1–5, 11). The ASI and its modified versions have strong psychometric properties, including internal consistency, test–retest reliability, criterion validity, convergent, and discriminant validity (Allan et al., 2014; Dehon et al., 2005; Reiss et al., 1986; Rifkin et al., 2015; Rodriguez et al., 2004; Taylor et al., 2007; Vujanovic et al., 2007). Although the Anxiety Sensitivity Index is often used as a unidimensional measure (Asmundson et al., 2011), previous studies have found multidimensional latent structure, identifying three, lower-order factors (i.e., physical, social, and cognitive domains), which load onto a single, higher-order, general factor (Asmundson et al., 2011; Calamari et al., 2008; Dehon et al., 2005; Farris et al., 2015; Taylor et al., 2007; Vujanovic et al., 2007; Walsh et al., 2004). In the present review, 4 out of 6 included studies reported an overall ASI score (see "Appendix D," studies 1, 2, 5, 11) and only two studies reported on other ASI facets, such as its physical, cognitive, and social domains (see "Appendix D," studies 3, 4).

The remaining five included studies used Child Anxiety Sensitivity Index (CASI; Muris, 2002; Silverman et al., 1991) to assess fear of anxiety-related symptoms in children and adolescents. The CASI has also demonstrated strong psychometric properties, including internal consistency, criterion, concurrent, and discriminant validity (Kearney et al., 1997; McLaughlin et al., 2007; Muris et al., 2001; Rabian et al., 1999). Some previous studies have found multidimensional factor structure for

CASI (Adornetto et al., 2008; Bernstein & Zvolensky, 2007; Essau et al., 2010; Lambert et al., 2004; Muris et al., 2001; Silverman et al., 2003; Weems et al., 2002, 2010), however, in the present review, studies have only relied on reporting of the overall CASI score (see "Appendix D," studies 6–10).

Main Results

Systematic Review

Table in the "Appendix D" displays a summary of the main findings from the included studies. Given that all studies used a cross-sectional design, the main findings are categorized according to the temporal aspects of the collected data (retrospective versus present). Thus, studies that examine participants' past learning experiences, such as those that rely on adults' reports of their childhood learning history, are classified as *retrospective learning experience studies*. In contrast, studies that focus on the ongoing or most recent learning experiences of children and adolescents are categorized as *present learning experience studies*. In addition, as the majority of the included studies combined negative information transmission and parental reinforcement/punishment in their analyses, these pathways are also combined in the main results to maintain consistency and facilitate comparison across studies (see Fig. 2).

Vicarious Fear Pathway *Retrospective learning experience studies.* The relationship between vicarious learning experiences and the AS was examined in 6 studies, in which childhood recollection of vicarious learning from parents was assessed by means of retrospective questionnaires (see "Appendix D," studies 1–5, 11). These studies collectively found that adults with heightened AS retrospectively reported more experiences involving observation of parental fear reactions in response to anxiety-related symptoms (McGinn et al., 2015; Stewart et al., 2001; Watt & Stewart, 2000; Watt et al., 1998, 2008). Only one study did not find a significant correlation between vicarious fear learning pathway and AS (Leen-Feldner et al., 2008; see "Appendix D," study 11). Two studies examined the relationship between vicarious fear pathway and the physical, social, and cognitive components of AS (see "Appendix D," studies 3 and 4). Both studies found a significant correlation with the physical component of AS. However, the results were mixed for the cognitive and social components. One study reported a significant association with the cognitive component but not the social (Watt et al., 2008), while the other found a significant association with the social component but not the cognitive (Stewart et al., 2001).

Present learning experience studies. Overall, 3 studies investigated the relationship between children's and

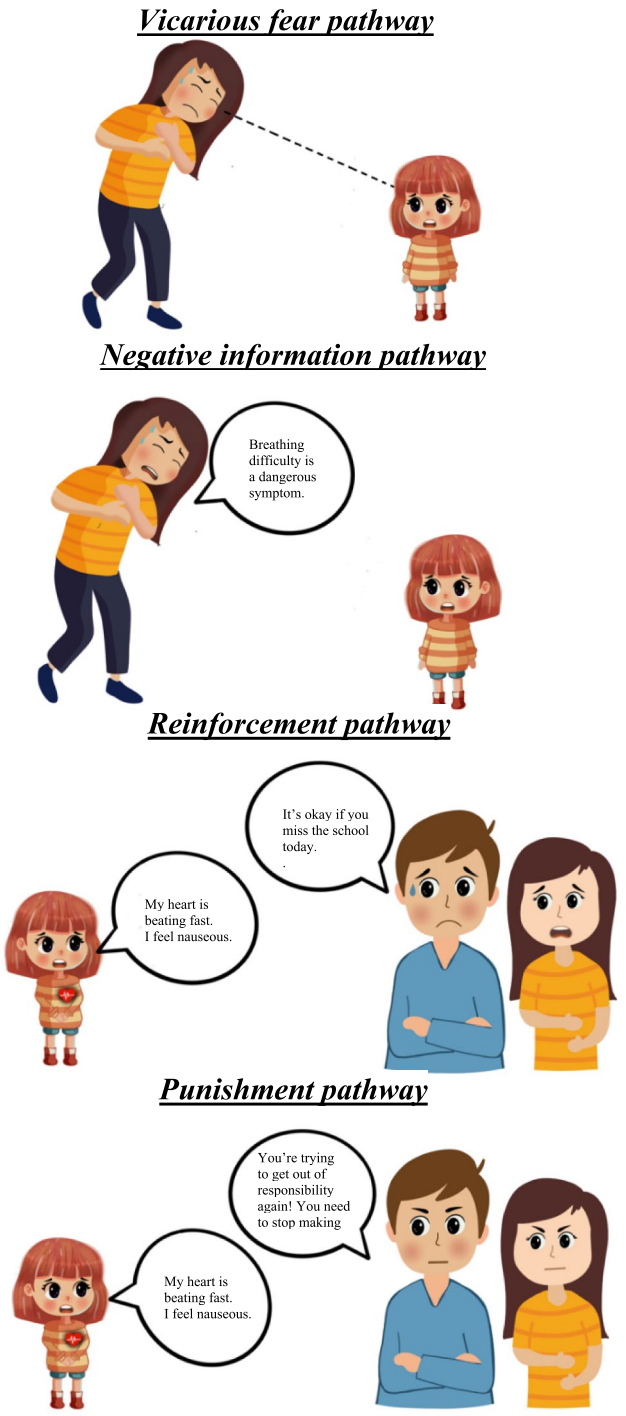

Fig. 2 Illustration of fear learning pathways. Illustration of vicarious fear pathway, in which the child observes the fear reaction of a parent experiencing anxiety symptom (e.g., difficulty breathing). Illustration of negative information pathway, in which the parent verbally transmits threat information about anxiety symptoms by informing the child about their fear and belief about the dangerousness of anxiety symptoms. Illustration of parental reinforcement of anxious behavior (e.g., parents supporting their child in avoiding responsibilities such as going to school and giving child attention by providing special treatment in response to child's complaint such as nausea or heart palpitations). Illustration of parental punishment of anxious behavior (e.g., parents not taking their child's complaints seriously and showing disapproval)

adolescents' current vicarious fear learning experiences and AS (see "Appendix D," studies 6, 7, 10). Out of 3, one study found that this pathway was positively associated with AS levels (Stassart et al., 2017), whereas another did not find a significant correlation between vicarious fear learning and adolescents' AS (Muris et al., 2001). An additional study assessed vicarious fear learning pathway and AS but did not report correlation between these two variables (Muris & Meesters, 2004).

Negative information, Reinforcement, and Punishment *Retrospective learning experience studies.* The fear learning pathway based on negative information, reinforcement, and punishment has been investigated in six studies (see "Appendix D," studies 1–5, 11), by asking adults to recall when their parents shared **negative information** (e.g., "Did your parents warn you of the possible dangers of your symptoms?"), **negative reinforcement** (e.g., "When you had these symptoms prior to age 18, did your parent encourage you to stay home from school? Were you excused from doing school homework?"), **positive reinforcement** (e.g., "Did you receive special care? Were you allowed to do things which were otherwise not allowed, such as watching television or staying up late?"), and **parental punishment** ("Were you made to feel responsible for having caused your symptoms? Did you feel left alone?"). The findings from these studies revealed a significant association between these childhood fear learning experiences and AS, suggesting that parents' transfer of negative information about anxiety symptoms, reinforced behaviors, or administered punishment are associated with the elevated levels of AS in adulthood (Leen-Feldner et al., 2008; McGinn et al., 2015; Stewart et al., 2001; Watt & Stewart, 2000; Watt et al., 1998, 2008). Two studies examining the association between negative information, reinforcement, and punishment on various aspects of AS (see "Appendix D," studies 3 and 4) found significant correlations for the physical and social dimensions of AS. However, results were mixed for the cognitive dimension, with one study (Watt et al., 2008) showing a significant association, while the other (Stewart et al., 2001) did not.

Present learning experience studies. Five studies assessed present learning experiences by asking children and adolescents to report on their parents' verbal expressions of the idea that anxiety-related symptoms might be dangerous (e.g., 'Do your parents warn you of the possible dangers of your anxiety symptoms?'), parental reinforcement (e.g., 'When you have these symptoms, do your parents allow you to stay home from school?'), and parental punishment (e.g., 'When I experience these bodily symptoms, my mother will not take me seriously') (see "Appendix D," studies 6–10). Of these five studies, four reported a significant correlation between these learning experiences and anxiety sensitivity (AS) (Knapp et al., 2013; Muris et al., 2001; Stassart et al., 2017). Out of five, one study found that clinic-referred children and adolescents with these experiences also tend to have greater levels of AS (Holly & Pina, 2015). This study investigated the relationship between these learning experiences and AS in a sample of both Caucasian and Hispanic/Latino children and adolescents, finding a significant correlation between these fear learning pathways and AS in both groups. Another study investigated the relationship between parental sharing of negative information, reinforcement, punishment, and AS but did not report correlations between these variables (Muris & Meesters, 2004).

Meta-analysis

The estimated overall effect across all included studies ($k = 10$) and effect sizes ($u = 36$) was $r = 0.24$, $p < 0.01$, 95% CI [0.13–0.35], indicating a small, but significant relationship between learning experiences and AS (see Fig. 3 for forest plot). Heterogeneity across the studies was not significant ($Q_{35} = 15.190$, $p = 0.999$). Heterogeneity at level 3 (between studies) was at least small as indicated by I^2-$_{\text{level 3}} = 36.94\%$ (Higgins, 2003). Despite minor variation of the true effect between studies, we employed moderator analyses to assess the effect of essential study-level variables on differences in effects (see "Appendix C").

Our moderator analyses did not yield a significant moderating effect of learning pathways ($F = 1.054$, $B = -0.088$, SE = 0.086, $p = 0.312$, $df = 33$). The type of study design, however, significantly moderated the relationship between learning experiences and AS ($F = 6.31$, $B = 0.285$, SE = 0.113, $p = 0.0169$, $df = 34$). For studies assessing past learning experiences, using retrospective questionnaires, the overall association was smaller, but still statistically significant ($r = 0.16$, $t = 3.481$, $p = 0.001$). In contrast, for studies assessing present learning experiences, we found a higher overall effect ($r = 0.438$, $t = 2.512$, $p = 0.0169$), suggesting that the relationship between learning experiences and AS varies depending on whether the learning experiences are assessed retrospectively or not (see "Appendix C").

Similarly, moderator analyses revealed a significant effect of sample age group ($F = 6.31$, $B = 0.285$, SE = 0.113, $p = 0.017$, $df = 34$), indicating a greater effect for children and adolescents ($r = 0.438$, $t = 2.512$, $p = 0.017$), and a lower, but significant effect for adults ($r = 0.160$, $t = 3.48$, $p = 0.001$). While learning experiences do influence AS in adults, the stronger effect in children and adolescents suggests that learning experiences are more strongly associated with AS in younger populations (see "Appendix C").

The proportion of females within a sample ($F = 1.617$, $B = -0.007$, SE = 0.005, $p = 0.212$, $df = 34$) and the ethnic composition of the sample ($F = 0.665$, $B = -0.170$,

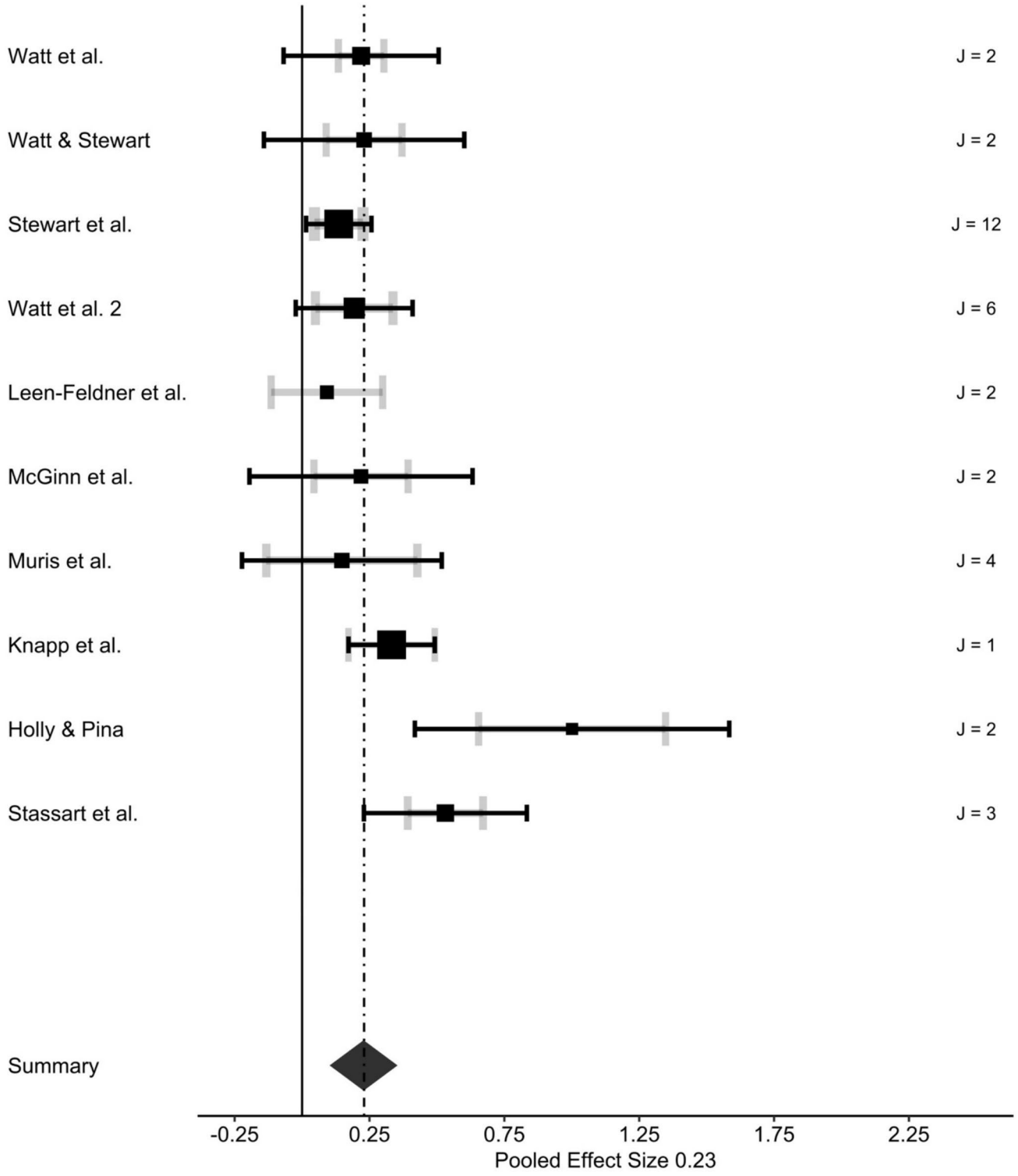

Fig. 3 Forest plot of effect sizes

SE = 0.209, $p = 0.423$, $df = 24$) did not significantly moderate the relationship between the learning experiences and AS (see "Appendix C").

Discussion

The influence of fear learning pathways on the development of childhood fears has been well established in prior

systematic reviews and meta-analyses (Askew & Field, 2008; Fisak & Grills-Taquechel, 2007; King et al., 1998; Lebowitz et al., 2016; Nimphy et al., 2023, 2024). However, these reviews have predominantly focused on investigating learning pathways related to fear of external threats, such as novel animals, snakes, or spiders. In contrast, the literature on learning pathways in relation to internal threats, such as fear of anxiety-related symptoms or AS, has not yet been systematically reviewed. To address this gap, the present systematic review and meta-analysis synthesized findings from individual studies examining the relationship between parent-to-child fear learning pathways and anxiety sensitivity (AS). The results revealed significant associations between childhood learning experiences—such as vicarious fear learning, negative information, reinforcement, and punishment, occurring within the family environment—and AS, suggesting that these pathways are also important to consider in the context of AS. The meta-analysis demonstrated a small but significant relationship between all learning pathways and AS ($r = 0.24$, $p < 0.01$, $k = 10$, $u = 36$), further confirming that these pathways extend beyond external to internal threats.

While individual studies have demonstrated associations between fear learning pathways and AS, they have often yielded inconsistent findings due to variations in methodology, sample characteristics, and study design. By systematically reviewing and aggregating findings across individual studies, our meta-analysis not only consolidates these findings into a single, more robust estimate but also reveals that the impact of these learning pathways is significantly moderated by age and study design, providing novel insights into when and how these pathways may be most influential. Importantly, our results suggest that childhood and adolescence may represent sensitive periods during which fear learning pathways exert stronger effects, supporting the need for early interventions. This quantitative synthesis also helps clarify previous inconsistencies by demonstrating that assessments of present learning experiences produce stronger effects than retrospective reports of learning experiences, emphasizing the need for methodological improvements in future research. Each of the key findings and the implications for theory and intervention are discussed below.

One key finding of our meta-analysis was that the relationship between fear learning pathways and AS varied depending on how learning experiences were assessed. Studies that examined present learning experiences found a stronger association with AS compared to those relying on retrospective reports of childhood learning experiences. Although cross-sectional studies relying on retrospective questionnaires are an important source of evidence that have confirmed the significant association between fear learning pathways and AS, they also come with limitations. One potential limitation of retrospective studies is their reliance on participants' recall of past learning experiences, which may introduce bias or inaccuracies due to memory distortions or the subjective interpretation of past events. This finding suggests that future research should prioritize assessments of fear learning pathways using longitudinal research designs, as they may offer a more accurate representation of how fear learning pathways might be related to AS. Additionally, these results have implications for clinical interventions, highlighting the importance of focusing on present learning experiences in therapeutic settings to prevent and mitigate AS in children and adolescents.

Our meta-analytic results also revealed that age significantly moderates the relationship between fear learning pathways and AS, with stronger associations in children and adolescents compared to adults. This finding is not surprising as it aligns with developmental research suggesting that children and adolescents are particularly reliant on their parents to interpret and respond to their environment (Allen et al., 2023). Given their still-developing cognitive and emotional regulation skills, children and adolescents may be more reliant on parental behavioral cues to assess whether bodily symptoms are benign or threatening. Alternatively, it is possible that learning experiences reported by children and adolescents are more recent and emotionally salient, making parental modeling of fear, verbal information about threats, and parental reinforcement or punishment more impactful. In contrast, adults who have retrospectively reported on their childhood learning experiences may have reframed those experiences, potentially weakening the relationship between childhood fear learning pathways and their current AS levels. Thus, the age at which learning experiences occur is an important factor to consider in future research investigating parent-to-child fear learning pathways and AS.

Interestingly, our meta-analysis found that the type of fear learning pathway did not significantly moderate the relationship between learning pathways and AS. This may suggest that these pathways do not operate independently but rather co-occur and amplify each other's impact. For example, a child who observes a parent reacting fearfully to anxiety symptoms may also receive verbal warnings about the dangers of those symptoms. This interpretation aligns with existing fear acquisition models, which posit that fear learning pathways do not operate in isolation in the context of external threats (Field, 2006; Field & Purkis, 2011; Field & Storksen-Coulson, 2007; Mineka & Zinbarg, 2006; Rachman, 1977). However, measurement inconsistencies across reviewed studies (e.g., some studies combining pathways rather than assessing them separately) may have made it difficult to isolate the unique contribution of each pathway to AS. Another likely explanation is the limited number of studies examining each learning

pathway separately, resulting in insufficient power to detect significant effects. Thus, future research should aim to assess each pathway individually or utilize standardized measures that better distinguish between these pathways in relation to AS.

In contrast to study design and age, gender and ethnicity did not significantly moderate the relationship between fear learning pathways and AS. While some prior studies have found gender differences in AS levels in adult and youth populations (Deacon et al., 2002; Muris et al., 2001; Stewart et al., 1997; van Widenfelt et al., 2002; Walsh et al., 2004), our findings suggest that the fear learning pathways related to AS may operate similarly across males and females. Likewise, our results indicate that the association between fear learning pathways and AS is relatively comparable across ethnic groups. However, given that the studies in our meta-analysis were predominantly conducted in Western populations, future research should examine fear learning pathways in more diverse and representative samples. Expanding research to non-Western contexts would help clarify whether sociocultural factors may influence the relationship between fear learning pathways and AS.

Although our review largely supports the relationship between fear learning pathways and AS, some studies have reported discrepant findings across pathways. For example, one study found a non-significant correlation between vicarious fear learning and adolescents' AS but observed significant associations for negative information, reinforcement, and punishment (Muris et al., 2001). Developmental research on AS has suggested that younger children, compared to adolescents, may lack the cognitive capacity to interpret anxiety-related symptoms in a catastrophic manner (Chorpita & Lilienfeld, 1999; Nelles & Barlow, 1988). However, other studies indicate that while younger children can recognize anxiety symptoms, they may struggle to make internal attributions or provide logical reasoning for these symptoms (Muris et al., 2008, 2010b; Weems et al., 1998, 2021). Given their greater reliance on parental behavioral cues, younger children may be particularly susceptible to vicarious fear learning pathway, whereas adolescents, with their more advanced cognitive capacities, may be more influenced by pathways such as negative information or reinforcement (Allen et al., 2023). However, given considerable age variability across the reviewed studies, with some studies focusing only on children, others only on adolescents, and some combining both age groups, future research should investigate whether different fear learning pathways vary in their influence at different developmental stages.

One striking pattern across our review was that most included studies relied on cross-sectional methodologies, in non-clinical populations, to investigate the relationship between fear learning pathways and AS. While these studies provide valuable insights into the relationship between fear learning pathways and AS, they cannot establish causality. This contrasts with previous research using experimental paradigms to investigate and demonstrate that parent-to-child learning pathways contribute to the onset of fear in response to external threats (e.g., snakes, strangers) (Burstein & Ginsburg, 2010; De Rosnay et al., 2006; Dubi et al., 2008; Gerull & Rapee, 2002; Marin et al., 2020; Muris et al., 2010a). Such findings align with contemporary fear acquisition models, which suggest that fear learning pathways operate through associative learning mechanisms (Aktar & Pérez-Edgar, 2024; Askew & Field, 2008; Field, 2006; Olsson & Phelps, 2007; Mineka & Cook, 1993; Mineka & Zinbarg, 2006). For example, in vicarious fear learning, a recent study using vicarious conditioning paradigm demonstrated that children could acquire fear of a previously neutral conditioned stimulus (CS) after observing a parent's fearful reaction to it. The parent's fearful reaction serves as an unconditioned stimulus (US), leading the child to associate the previously neutral stimulus with threat and subsequently exhibit a conditioned fear response (Marin et al., 2020; Dunne & Askew, 2013; for a review, see Skversky-Blocq et al., 2021). While this research provides compelling evidence for the role of vicarious learning in fear acquisition, no studies to date have used conditioning paradigms to examine whether similar processes occur in the context of anxiety-related symptoms. This gap highlights the need for experimental research to investigate children's and adolescents' fear acquisition of anxiety-related symptoms through these learning pathways.

Although the included studies provide evidence that parent-to-child fear learning pathways are related to AS, the cross-sectional nature of these studies prevents conclusions about whether these pathways contribute to the onset of AS or shape its trajectory over time. If parental behaviors toward bodily symptoms, through fear learning pathways, increase offspring's fear of these symptoms, they may also reinforce avoidance, potentially contributing to the maintenance of AS (Lebowitz et al., 2016; Bunaciu et al., 2014; Weems et al., 2002). However, given the lack of longitudinal studies, this remains a critical gap, particularly since both AS and parental behaviors have been implicated in the onset and persistence of anxiety-related symptoms.

While the includes studies in our review have focused on how parental behaviors are related to child AS, emerging evidence suggests that this relationship may be bidirectional, with children's AS potentially influencing parental behaviors via these fear learning pathways. For instance, two experimental studies have shown that adolescents who describe their bodily symptoms in an anxious manner elicit greater parental reinforcement behaviors in response to those symptoms, such as encouraging rest or avoidance (e.g., telling the child to lie down) (Bilsky et al., 2018a, b). These

findings suggest that child AS-related distress influences parental behaviors via reinforcement pathway, which may inadvertently reinforce avoidance, thereby creating a vicious cycle that could maintain AS over time. Future longitudinal research is needed to explore whether reinforcement or other fear learning pathways contribute to AS maintenance and, if so, whether interventions targeting these parental responses could help disrupt this cycle.

Conceptual Model

In sum, our findings highlight that childhood learning experiences, such as vicarious learning, negative information transmission, reinforcement, and punishment, are significantly and positively correlated with fear of anxiety-related symptoms or AS (see Fig. 4). Based on the available evidence and the findings of our meta-analysis, we developed an initial conceptual model to illustrate how fear learning pathways are related to the AS (see Fig. 4). As shown in Fig. 4, this model highlights established significant associations supported by prior research in solid lines, whereas associations supported by the current meta-analysis are shown in dashed lines. More specifically, a significant association between parents' AS and parents' psychopathology has been demonstrated, with previous research showing that elevated AS levels are associated with subsequent anxiety and depressive disorders in adults (Naragon-Gainey, 2010; Hovenkamp-Hermelink et al., 2019; Olatunji & Wolitzky-Taylor, 2009; Schmidt et al., 2006; Spinhoven et al., 2017). Similar to findings reported for adults, AS has been found to serve as a pertinent risk marker for subsequent anxiety psychopathology in children and adolescents (Hale & Calamari, 2006; Noël & Francis, 2011; Weems et al., 1997, 2002). Although AS is correlated with anxiety symptoms and later psychopathology in adult and child population (Joiner et al., 2002; Schmidt et al., 1997, 1999; Tsao et al., 2005), the parent-to-child fear learning pathways related to AS have not been fully elucidated. The present meta-analysis provided evidence for the significant association between the learning pathways and AS, suggesting that exposure to such learning experiences, whether through verbal communication, modeling, or reinforcement/punishment, is related to AS. The relationship between learning pathways and AS was found to be stronger when current learning experiences were assessed, indicating that recent interactions may have a more immediate and impactful role in shaping AS. Moreover, this relationship appeared to be more pronounced in younger populations, such as children and adolescents, compared to adults. These findings suggest that developmental stages may influence the extent to which individuals are susceptible to learning pathways, reinforcing the importance of considering age when evaluating the learning pathways in the context of AS. However, the moderating effects of gender and ethnic composition were not significant, indicating that these demographic variables may not substantially alter the relationship between learning pathways and AS. Overall, these findings suggest that further investigation of pathways through which fear of anxiety-related symptoms or AS is learned is necessary, including the need for targeted preventive interventions that address AS via these specific fear learning pathways. Future research should prioritize longitudinal and experimental methodologies to further investigate these relationships and develop interventions that can ameliorate the risk of developing anxiety-related psychopathology.

Clinical Implications

A deeper understanding of the learning experiences involved in relation to AS may inform and significantly improve the existing treatment interventions and prevention strategies, while also leading to the development of targeted prevention programs designed particularly to address fear learning of anxiety symptoms. In our meta-analysis, we found a small but significant association between learning pathways and AS, demonstrating that vicarious learning experiences, verbal learning experiences, and parental reinforcing and punishing behaviors during childhood and adolescence are all significantly associated with elevated levels of AS. Given these findings, parent-based treatment interventions should aim to target all these learning pathways. It could be possible that by addressing each pathway in an integrated manner, the efficacy of interventions may be enhanced, thereby potentially preventing later onset of anxiety sensitivity.

At present, however, preventive interventions and specific programs targeting these learning pathways and additionally addressing AS are lacking. In fact, there are only a few intervention studies aimed at preventing the transmission of anxiety in the offspring of anxious parents (Cartwright-Hatton et al., 2018; Ginsburg et al., 2015, 2020). However, these intervention studies have demonstrated effectiveness in reducing anxiety by modifying fear and anxiety-enhancing parental behaviors (for a review, see Chapman et al., 2022). For example, parent-based interventions targeting parent-to-child interactions, such as providing psychoeducation to reduce parental modeling of anxious behaviors, have shown positive outcomes in reducing the overall anxiety symptoms and decreasing rates of onset of anxiety disorders in children of families receiving such intervention (Cartwright-Hatton et al., 2018; Ginsburg et al., 2015, 2020).

Additionally, some interventions addressing somatic symptoms also exist, but these have primarily focused on the augmentation of child therapy, including cognitive-behavioral therapy, with a family-based component (for a review, see Coakley & Wihak, 2017; Levy et al., 2010; Zagustin, 2013). For example, one intervention study that has addressed social

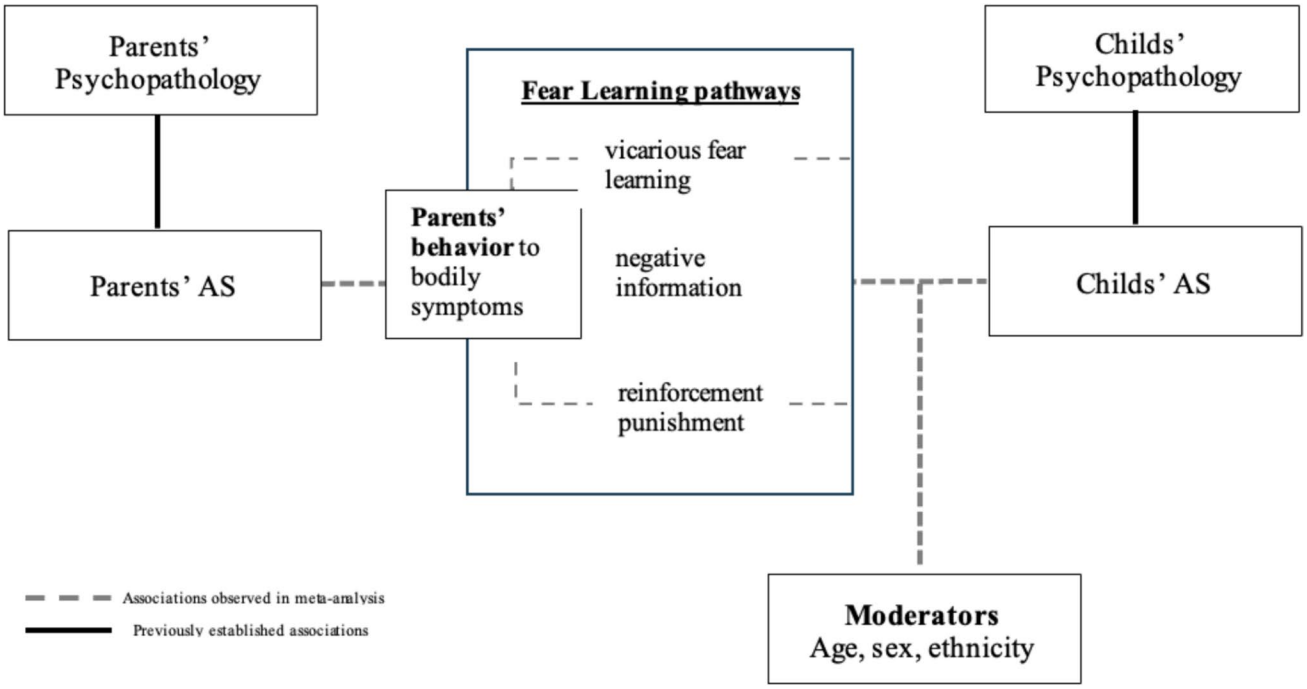

Fig. 4 Conceptual model illustrating associations between parent-to-child learning pathways and anxiety sensitivity (AS). Solid lines represent significant associations identified in previous research, such as the link between parents' AS and their own psychopathology (Olatunji & Wolitzky-Taylor, 2009; Schmidt et al., 2006; Taylor et al., 1996). The significant relationship between AS and subsequent psychopathology in children is also depicted in the upper right corner of the figure (Noël & Francis, 2011; Weems et al., 1997). Dashed lines represent associations observed in the current meta-analysis, which found a significant relationship between parent-to-child fear learning pathways (e.g., vicarious fear, negative information, and reinforcement/punishment) and AS. The strength of these associations varied based on the recency of reported learning experiences and offspring age, with stronger associations observed in younger populations (children and adolescents). However, gender and ethnic composition did not significantly moderate these associations

learning strategies to modify family responses to illness and wellness behaviors, showed reduction in pain and gastrointestinal symptoms in children and adolescents after parents reduced protective responses to children's symptoms and decreased maladaptive beliefs related to children's pain (Levy et al., 2013; Levy et al., 2010).

Adapting techniques used in these prevention studies, particularly those aimed at reducing the adverse effects of learning pathways, could also be efficient in preventing or reducing AS levels. Future interventions should consider incorporating learning pathways as an added component, teaching parents how their modeling, verbal messages, reinforcement, or punishment may increase children's fear of anxiety symptoms. In fact, current treatment and future preventive intervention programs should train parents how to identify and modify these behaviors and teach parents to implement positive modeling, communicate positive information regarding bodily symptoms, and refrain from reinforcing (e.g., special treatment, treats) or punishing behaviors.

Overall, findings from intervention studies suggest that parent-based interventions could be delivered as a standalone, alternative prevention strategy (with parents as primary agents of behavioral change), especially in cases where child treatment is not feasible (e.g., younger children).

Limitations and Future Directions

Although the present systematic review and meta-analysis provide a comprehensive overview of the literature elucidating the role of learning pathways and fear of anxiety symptoms, the following limitations should be considered.

First, given that all the included studies employed a cross-sectional design, the limitation of the present review is that the cross-sectional nature of the reviewed studies and the lack of longitudinal or experimental studies prevent us from drawing any causal conclusions. An additional methodological limitation is the use of retrospective questionnaires in several included studies, due to the memory bias that is inherent in retrospective recall of learning experiences (e.g., adults reporting on their childhood learning experiences). To address such methodological limitations, future studies should employ either longitudinal designs or experimental paradigms to investigate learning of fear of anxiety symptoms.

Second, another limitation of the review is the exclusion of other anxiety-related constructs and measures that might have been related to the measures of interest (i.e., fear of anxiety-related symptoms and learning pathways) but were beyond the scope of this review. Given that our results primarily rely on the Anxiety Sensitivity Index as a measure of fear of anxiety-related symptoms, other constructs or measures that might be related might have been excluded. Future studies should also aim to include a broader range of anxiety-related constructs and measures, beyond just anxiety sensitivity, to explore how other dimensions of anxiety may interact with these learning pathways. By examining constructs such as trait anxiety, intolerance of uncertainty, and worry, a broader insight might be uncovered regarding mechanisms that could contribute to the development of fear of anxiety symptoms. Incorporating these constructs could provide a more nuanced understanding of how various fear-related constructs (e.g., fear of anxiety symptoms, intolerance of distress) intersect with learning experiences, potentially offering more comprehensive insights for interventions targeting anxiety psychopathology.

Third, the results presented in our review and meta-analysis relied primarily on the studies conducted in North America and Western Europe. Additionally, the samples consisted predominantly of Caucasian participants, with a few studies including Hispanic/Latino, Black/African American, or Asian participants. Given that previous research shows that anxiety sensitivity is linked to anxiety symptoms and disorders in heterogeneous racial and ethnic adult (Ghisi et al., 2016; Lim & Kim, 2012; Sandín et al., 2007; Talkovsky & Norton, 2014; Zvolensky et al., 2003) and youth population (Chorot et al., 2023; Essau et al., 2008, 2011; Fernández-Valdés et al., 2017; Fullana et al., 2003; Lambert et al., 2004), the homogeneity of samples in studies included in our review limits representatives and generalizability of our findings. Thus, future studies would benefit from investigating the role of learning pathways and anxiety sensitivity in a more demographically inclusive and culturally diverse population. However, considering that we limited our search to peer-reviewed studies published only in English, we may have missed other relevant studies published in other languages, as well as those using different search terms or databases, which could have provided increased generalizability of the findings presented in this review.

A notable limitation of the present review is the reliance on studies that predominantly reported the overall anxiety sensitivity scale, rather than its multidimensional subscales (e.g., physical social, cognitive). Based on our systematic search, only two reviewed studies specifically assessed different facets of AS, producing mixed results. These discrepancies suggest that the relationship between learning pathways and the specific facets of AS may be more complex than initially thought. Additionally, the reliance on the overall anxiety sensitivity and the absence of data on specific facets of AS limit our ability to draw conclusions on the relationship between these learning experiences and different facets of AS. Future research should aim to investigate these facets more thoroughly, employing larger sample sizes and longitudinal designs to clarify whether different learning pathways uniquely contribute to each component of AS. By doing so, future research may provide more nuanced insights with important implications for developing more targeted interventions that address the distinct elements of anxiety sensitivity.

Appendix A

Search terms applied to four electronic databases: PubMed, Embase, PsychINFO, Web Science

Search category	Search terms
1 *fear learning pathways*	Vicarious learning *OR* vicarious fear learning *OR* observational learning *OR* observational fear learning *OR* social learning *OR* social fear learning *OR* social fear transmission *OR* modeling *OR* modeling *OR* informational learning *OR* instructed fear learning *OR* verbal information *OR* verbal threat information *OR* learning exp* *OR* learning history *OR* reinforcement learning *OR* punishment *OR* instrumental learning
	AND
2 *anxiety-related symptoms*	Anxiety sensitivity *OR* anxiety symptom* *OR* anxiety-related symptom* *OR* anxiety sensation* *OR* bodily symptom* *OR* bodily sensation* *OR* physical symptom* *OR* physical sensation* *OR* somatic symptom* *OR* somatic sensation* *OR* panic *OR* panic symptom* *OR* panic-related symptom* *OR* panic attack* *OR* arousal reactive sensation* *OR* health anxi* *OR* illness anxi* *OR* illness behavior *OR* illness behaviour *OR* hypochondria* *OR* hypochondriacal worry *OR* somatic-complaint*
	AND
3 *population*	Child* *OR* adolesc* *OR* pediatric *OR* paediatric *OR* offspring *OR* youth *OR* young adult *OR* parent* *OR* mother* *OR* maternal *OR* father* *OR* paternal *OR* caregiver* *OR* guardian* *OR* famil* *OR* student*

The Boolean operator OR was used within each search category to combine search terms so that results contain at least one of the terms. The Boolean operator AND combines three search categories so that results contain all the search terms

Appendix B

Quality rating of the included studies

Authors	Item														Quality rating	%
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
1. Watt et al. (1998)	Yes	Yes	NR	Yes	No	No	Yes	Yes	Yes	NA	Yes	NA	NA	Yes	Fair	72
2. Watt and Stewart (2000)	Yes	Yes	NR	Yes	No	No	Yes	Yes	Yes	NA	Yes	NA	NA	Yes	Good	81
3. Stewart et al. (2001)	Yes	Yes	NR	Yes	No	No	Yes	Yes	Yes	NA	Yes	NA	NA	Yes	Good	81
4. Watt et al. (2008)	Yes	Yes	NR	Yes	No	No	Yes	Yes	Yes	NA	Yes	NA	NA	Yes	Fair	72
5. McGinn et al. (2015)	Yes	Yes	NR	Yes	No	No	Yes	Yes	Yes	NA	Yes	NA	NA	Yes	Good	81
6. Muris et al. (2001)	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	NA	Yes	NA	NA	Yes	Fair	54
7. Muris and Meesters (2004)	Yes	Yes	NR	Yes	No	No	No	Yes	Yes	NA	Yes	NA	NA	Yes	Fair	72
8. Knapp et al. (2013)	Yes	Yes	NR	Yes	No	No	No	Yes	Yes	NA	Yes	NA	NA	Yes	Fair	63
9. Holly and Pina (2015)	Yes	Yes	NR	Yes	No	No	No	Yes	Yes	NA	Yes	NA	NA	Yes	Fair	72
10. Stassart et al. (2017)	Yes	Yes	NR	Yes	No	No	No	Yes	Yes	NA	Yes	NA	NA	Yes	Fair	72
11. Leen-Feldner et al. (2008)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	NA	Yes	NA	NA	Yes	Good	81

Item 1 = Was the research question or objective in this paper clearly stated?; Item 2 = Was the study population clearly specified and defined; Item 3 = Was the participation rate of eligible persons at least 50%?; Item 4 = Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?; Item 5 = Was a sample size justification, power description, or variance and effect estimates provided?; Item 6 = For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?; Item 7 = Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?; Item 8 = For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?; Item 9 = Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Item 10 = Was the exposure(s) assessed more than once over time?; Item 11 = Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Item 12 = Were the outcome assessors blinded to the exposure status of participants?; Item 13 = Was loss to follow-up after baseline 20% or less?; Item 14 = Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)

NR not reported, *NA* not applicable

Appendix C

Meta-regression results of categorical moderators

Effect	*df*	*F*	*B*	*r*	SE	*t*	95% CI
Overall Effect Size	35			**0.236****	0.056		[0.127, 0.355]
Fear Learning Pathways	33	1.054					
Negative information, reinforcement, punishment				0.283	0.071	4.073	[0.145, 0.436]
Vicarious fear pathway			−0.088	0.195	0.086	−1.027	[−0.263, 0.087]
Study Design	34	**6.310****					
Retrospective				0.161	0.046	3.481	[0.067, 0.257]
Present			0.277	0.438	0.113	2.512	[0.054, 0.515]
Age Group	34	**6.310****					
Adults				0.160	0.047	3.481	[0.068, 0.257]
Children and Adolescents			0.278	0.438	0.113	2.512	[0.054, 0.515]
Ethnic Group	24	0.664					
Homogeneous				0.396	0.169	2.468	[0.068, 0.769]
Mixed			−0.168	0.228	0.208	−0.815	[−0.60, 0.260]

$p < 0.1$, *$p < 0.05$, **$p < 0.01$. Significant findings are presented in bold. Fisher *z*-values used in analyses were converted back to *r*-values for presentation

Appendix D

Detailed study description and summary

#	Study		Study characteristics		Subjects			Results			
	First author, year	*Study type/ Methods*	*Sample*	*Age group*	*Country/ Ethnicity*	*Cases*	*Controls*	*Fear of anxiety-related symptoms*	*Learning pathway*	*Significant result*	
1	Watt et al. (1998)	Cross-sectional/ Retrospective questionnaire	Non-clincial	Adults	Canada	$N=543$ High ASI ($n=88$) ($M_{age}=20.4$, SD = 3.0; $f=63$) Medium ASI ($n=112$) ($M_{age}=20.8$, SD = 3.8; $f=70$) Low ASI ($n=88$) ($M_{age}=21.6$, SD = 4.6; $f=60$)	No control	Assessed with ASI Total score	Assessed with LHQ-Expanded	Vicarious, Negative information, reinforcement & punishment of cold and anxiety-related symptoms (LHQ)	High AS reported sig. more reinforcement and vicarious pathway of arousal reactive, arousal non-reactive symptoms vs. low AS group; All part reinforcement/ Negative information/punishment of arousal reactive sig. predicted ASI, but not vicarious learning of arousal reactive symptoms
2	Watt and Stewart (2000)	Cross-sectional/ Retrospective questionnaire	Non Clincial	Adults and their parents	Canada	students ($N=197$) ($M_{age}=21.9$, SD = 4.6; $f=156$)	No controls	Assessed with ASI Total score	Assessed with LHQ-Revised	Vicarious fear pathway, Negative information, reinforcement/punishment (LHQ)	Sig. association between AS and learning pathways of arousal reactive and non-arousal reactive symptoms;

#	Study		Study characteristics		Subjects			Results			
	First author, year	*Study type/ Methods*	*Sample*	*Age group*	*Country/ Ethnicity*	*Cases*	*Controls*	*Fear of anxiety-related symptoms*	*Learning pathway*	*Significant result*	
3	Stewart et al. (2001)	Cross-sectional/ Retrospective questionnaire	Non-clinical	Adults	Canada 71% Caucasian, 17% Asian, 12% Other ethnic group	$N=478$ ($M_{age}=21$, SD = 3; $f=317$)	No controls	Assessed with ASI-R Total, content scales	Assessed with LHQ-III	Vicarious fear pathway, reinforcement, Negative information, punishment (LHQ)	Learning history of arousal reactive and non-reactive symptoms associated with AS;
4	Watt et al. (2008)	Cross-sectional/ Retrospective questionnaire	Non-clinical	Adults	Canada 93% White	$N=192$ ($M_{age}=19.4$, SD = 3.5; $f=143$)	No controls	Assessed with ASI Total, Subscales	Assessed with LHQ-IV	Vicarious fear pathway, Negative information, Reinforcement/punishment (LHQ)	Sig. predictor of AS was transmission (vicarious, verbal, reinforcement) of anxiety-related symptoms
5	McGinn et al. (2015)	Cross-sectional/ Retrospective questionnaire	Non-clinical	Adults (18–77)	USA New York	$N=129$ ($M_{age}=42.5$, SD = 13.2; $f=99$)	No control	Assessed with ASI Total score	Assessed with LHQ-Modified	Vicarious fear pathway, reinforcement (LHQ)	Parental reinforcement and vicarious fear of anxiety symptoms was not sig. associated with fear if anxiety symptoms
6	Muris et al. (2001)	Cross-sectional	Non-clinical	Adolescents (12–14 years)	Netherlands	$N=52$ ($M_{age}=12.3$, SD = 0.5; $f=29$)	No controls	Assessed with CASI Total score	Assessed with LEI	Vicarious fear pathway, Negative information, and reinforcement (LEI)	Sig. association between AS and Negative information of pain and anxiety; no sig. association with reinforcement or vicarious fear pathway

#	Study		Study characteristics		Subjects			Results			
	First author, year	*Study type/ Methods*	*Sample*	*Age group*	*Country/ Ethnicity*	*Cases*	*Controls*	*Fear of anxiety-related symptoms*	*Learning pathway*	*Significant result*	
7	Muris and Meesters (2004)	Cross-sectional	Non-clinical	Children (8–13 years)	Netherlands, southern part	$N=190$ ($M_{age}=10.6$, SD = 1.0; $f=100$)	No Control	Assessed with CASI Total score	Assessed with LEI	Reinforcement, Negative information (LEI)	Trait anxiety, AS and Negative information of anxiety sig. predicted somatization symptoms in children
8	Knapp et al. (2013)	Cross-sectional	Non-clinical	Children and Adolescents (10–17 years)	USA 4.4% Hispanic/ Latino, 85% White/ Caucasian, 5.9% Asian, 7% Black/ African American, 7% American Indian, 3.3.% Other	$N=153$ ($M_{age}=14.66$ (SD = 2.18), $f=76$)	No Control	Assessed with CASI Total score	Assessed with LHQ-III	Negative information, Reinforcement (LHQ-III)	Positive association between AS and negative information reinforcement of arousal reactive symptoms but not arousal non-reactive symptoms
9	Holly and Pina (2015)	Cross-sectional	Clinical	Children and Adolescents (6–16 years)	USA 49% Hispanic/ Latino 51% Caucasian	$N=70$ ($M_{age}=9.86$, SD = 2.59; $f=35$)	No controls	Assessed with CASI Total score	Assessed with P-SABIS	Vicarious fear pathway, Negative information, reinforcement/ punishment (P-SABIS)	For Hispanic/ Latino and Caucasian children: reinforcement of anxious emotion expression was sig. associated with AS

#	Study		Study characteristics		Subjects			Results			
	First author, year	*Study type/ Methods*	*Sample*	*Age group*	*Country/ Ethnicity*	*Cases*	*Controls*	*Fear of anxiety-related symptoms*	*Learning pathway*	*Significant result*	
10	Stassart et al. (2017)	Cross-sectional	Non-clinical	Children (9–13 years) and their parents (mother & father)	Belgium 100% Caucasian	N = 200 (M_{age} = 10.7, SD = 1.19; f = 105) Mothers (n = 200) and fathers (n = 200) (M_{age} = 42.0, SD = 4.60)	No controls	Assessed with CASI Total score Other factors: child's femininity/expressive traits and masculine/emotional traits (CPAQ)	Assessed with LEI-II	Vicarious fear pathway, Negative information, reinforcement (LEI-II)	AS was sig. associated with mothers and fathers modeling and negative information of pain and anxiety-related symptoms Negative information and reinforcement of pain symptoms sig. predicted child's AS; Mother's modeling of anxiety symptoms was sig. associated with child's AS in children with high feminine/expressive traits (+ 1SD); father's modeling of anxiety symptoms was sig. associated with child's AS in children with high feminine/expressive (+ 1SD)

#	Study		Study characteristics		Subjects			Results		
	First author, year	*Study type/ Methods*	*Sample*	*Age group*	*Country/ Ethnicity*	*Cases*	*Controls*	*Fear of anxiety-related symptoms*	*Learning pathway*	*Significant result*
11	Leen-Feldner et al. (2008)	Cross-sectional	Non-clinical	Adults	USA 95% Caucasian 2.5%, African American and, 2.5% Asian	$N=93$ ($M_{age}=23.41$, SD = 8.56, $f=39$)	No controls	Assessed with ASI Total score	Assessed with LHQ-III	Vicarious fear pathway, Negative information, reinforcement, and punishment (LHQ)

PD panic disorder, *AS* anxiety sensitivity, *LHQ* Learning History Questionnaire, *ASI* Anxiety Sensitivity Index, *CASI* Childhood Anxiety Sensitivity Index, *LEI* learning experience interview, *LHQ-III* Learning History Questionnaire-III, *ASI-R* Anxiety Sensitivity Index-Revised, *ASI-3* Anxiety Sensitivity Index-3, *LEI-II* Learning Experience Index-second version (Stassart et al., 2017), *ASI-R* Anxiety Sensitivity Index-Revised, *CPAQ* Children's personality Attributes Questionnaire, *P-SABIS* parental socialization of anxious behaviors interview schedule

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Declarations

Conflict of interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflict of interest.

Ethical approval This review synthesizes existing research and is based on analysis of previously published data. It did not involve the collection or manipulation of published data. The review adheres to ethical guidelines and principles, and all data and findings are presented accurately and without bias.

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