Examining associations between second-hand smoke exposure in early childhood, respitory disease, and anxiety in adolescence.

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It is widely accepted that cigarette smoking is associated with physical health problems including lung cancer (Lodovici & Bigagli, 2009) and heart disease (Peto et al., 1992), which can be attributed to the toxic and carcinogenic substances present in tobacco products (American Cancer Society, 2021). Environmental tobacco smoke, also referred to as second-hand smoke, has been linked to poor physiological health outcomes in children and adults (World Health Organisation, 2007), and *in utero* exposure to maternal smoking has been linked to the development of health problems later in life (Burke et al., 2012). Recently, the scope of research has expanded to examining the effects of cigarette smoking on mental health outcomes (Goodwin et al., 2005), and evidence of relationships with distress, general anxiety, and depression has been found (McCabe et al., 2004). Based on such findings, it would be expected that second-hand smoke exposure would also be associated with unfavourable mental health outcomes, although the evidence for this is less concrete. A study of Scottish non-smoking adults found that higher second-hand smoke was associated with elevated levels of self-reported psychological distress (Hamer, 2010), while a study of Dutch adult participants found no significant relationship (Bot et al., 2013), prompting further examination of these associations.

Exposure to second-hand smoke is of particular concern in the context of child and adolescent health. Little is currently known about the long-term effects of second-hand smoke on mental health outcomes in children and adolescents (Hamer et al., 2011), and researchers highlight the utility of large-scale prospective cohort studies for examining this link (Burke et al., 2012). One cross-sectional study of adolescents found an increase in the prevalence of psychological distress in line with duration of second-hand smoke exposure

(Padrón et al., 2014), while another found evidence of a positive association between second-hand smoke exposure and generalised anxiety disorder (Bandiera et al., 2011).

In utero exposure to second-hand smoke is also associated with poor mental health outcomes. A study of several European countries found an association between *in utero* exposure and probable attention deficit hyperactivity disorder in children aged 6-11 (Kovess et al., 2014), and a British study found a strong association with hypomania and psychotic symptoms at age 22-23 (Mackay et al., 2016). A New Zealand-based longitudinal study found significant relationships between exposure to maternal smoking *in utero* and depression, conduct disorder and substance abuse at ages 16-18, but the relationship with general anxiety was not statistically significant (Fergusson et al., 1998).

Higher rates of smoking have been found among those with anxiety disorders (Morissette et al., 2007), which are characterised by excessive fear or anxiety beyond what would be considered a normal feeling of nervousness or anxiousness as a reaction to stress (American Psychiatric Association, 2021). Anxiety disorders include generalised anxiety disorder, panic disorder, agoraphobia, posttraumatic stress disorder, obsessive compulsive disorder, social phobia, specific phobia, and separation anxiety (Lijster et al., 2017), and these are particularly consequential because they can cause significant impairment to social and occupational functioning (Lijster et al., 2017). Approximately 5% of Australian children and adolescents report an anxiety disorder as their principal mental health condition (Lawrence et al., 2016), and these issues have the potential to continue into adulthood (Lijster et al., 2017). The presence of anxiety-related symptoms may prompt adolescents to self-medicate using tobacco products, perpetuating a cycle of smoking-related damage to both physical and mental health (Goodwin et al., 2005).

The relationship between second-hand smoke exposure and anxiety disorders is further complicated by the presence of respiratory illness. Second-hand smoke exposure in early childhood has been linked to increased risk of development of respiratory diseases including asthma (Burke et al., 2012), and respiratory illness in childhood has itself been linked to agoraphobia and panic disorder in adulthood (Craske et al., 2001), suggesting a more complex interaction between second-hand smoke exposure, respiratory illnesses, and anxiety-related disorders. There are several hypotheses regarding the direction of these relationships and the mechanism through which they may occur. The first proposes that smoking, or smoke exposure, leads to the development of anxiety disorders (including panic attacks) through reduced respiratory function (Goodwin et al., 2005; Johnson et al., 2000). The second proposes that adolescents with anxiety are at a higher risk of nicotine dependence (Johnson et al., 2000), and being exposed to second-hand smoke at home may increase this risk (Okoli & Seng, 2018). In those who are asthmatic, symptoms such as shortness of breath or chest tightness may be appraised by the individual as a signal of bodily distress or impending asthma exacerbation (Meuret et al., 2020), and may worsen the experience of anxiety or panic. Other hypotheses suggest a third factor, such as personality or genetic predisposition, which may explain why parents with poor mental health engage in smoking behaviours (Goodwin et al., 2005), and why their children may subsequently develop anxiety disorders while simultaneously developing respiratory illness through exposure to second-hand smoke. The timeframe between age of exposure to second-hand smoke and age at which health outcomes show measurable differences is also undetermined, as prospective studies examining second-hand smoke exposure and cognitive outcomes have generated inconsistent results (described in detail in a 2013 meta-analysis by Chen et al.). Therefore, if the detection of respiratory illness in an individual occurs before the detection of an anxiety disorder, it may lead parents or doctors to mistakenly believe that the first preceded the second. Children

who grow up in an environment where they are exposed to second-hand smoke must also attempt to reconcile this fact with the anti-smoking messages they receive at school (Holdsworth & Robinson, 2013), which may generate anxiousness regarding their own health and the health of their family members. Other factors which have been suggested to facilitate the relationship between second-hand smoke exposure and subsequent development of anxiety disorders include inner-city living (Butz et al., 2011), family history of anxiety issues (Goodwin et al., 2005) or severe respiratory illness (Craske et al., 2001) and neurotic personality type (Goodwin et al., 2005). Females are also at higher risk of developing an anxiety disorder than males (McLean et al., 2011).

Among those with asthma, the prevalence rate of anxiety disorders may be up to 45% (Meuret et al., 2020). Adolescents experiencing anxiety-related symptoms may be more likely to begin smoking and continue to smoke due to peer pressure, as a means of socialising, or because smoking behaviours have been modelled by their parents (Holdsworth & Robinson, 2013), and develop or exacerbate respiratory illness as a result. Smoking is prevalent among individuals with anxiety (Morissette et al., 2007), possibly due to the belief that the nicotine present in cigarettes eases anxiety symptoms, therefore individuals experiencing anxiety begin and continue to smoke to experience these anxiolytic effects (Goodwin et al., 2005). Morissette et al. (2007) note that studies examining this effect are unable to attribute anxiety reduction to nicotine directly, and instead suggest that the act of smoking draws the attention of the individual away from their anxiety symptoms (or from withdrawal symptoms, in the case of study participants who were regular smokers). A study of adolescent rats found an increase in anxiety-like behaviours following nicotine exposure, which persisted even after nicotine was withdrawn, suggesting that nicotine exposure may relate to elevated anxiety (Slawecki et al., 2013). This may indicate a bi-directional causal relationship between smoking behaviours and poor mental health outcomes, where smoking

exacerbates mental health issues and those with mental health issues smoke to experience relief (Bot et al., 2013; Goodwin et al., 2005). In adolescents with respiratory illness, the adoption of smoking behaviours carries the risk of worsening their pre-existing respiratory conditions while also contributing to mental ill health.

Research into child and adolescent health contributes to better understanding of risks and outcomes and has significant implications for population health. Determining which risk factors are associated with anxiety in adolescents in Australia can inform policy and interventions, with a view to decreasing the rate of incidence of anxiety disorders among Australians in the future. A qualitative study examining postpartum smoking behaviour found that for many participants, key motivators to smoking cessation included being made aware of the associated risks, and concerns for the health of their baby (Wen et al., 2015), therefore research into child and adolescent health may inform smoking cessation campaigns and interventions targeted towards parents who smoke.

The goal of this present study is to examine the relationship between parental smoking behaviours in early childhood, respiratory illness, and anxiety-related mental health outcomes in adolescents in an Australian context. This study is somewhat novel in that it focusses specifically on second-hand smoke exposure, adolescent anxiety symptoms as an outcome, and the possible moderating effects of respiratory illness. The first aim involves examining whether, and to what degree, certain factors have significant associations with measures of anxiety. These factors include maternal prenatal smoking, second-hand smoke exposure from parental smoking during early childhood, presence of asthma or other respiratory disease, family history of respiratory disease, family history of mental illness (depression or anxiety), and biological sex. Cabral & Patel (2020) note that the development of anxiety in adolescence involves genetic, temperamental, sociodemographic, environmental, and physiological factors, therefore I hypothesise that each factor will be

significantly associated with measures of anxiety, and that the presence of respiratory illness would be the most strongly associated factor. The second aim involves determining whether maternal prenatal smoking or parental smoking during early childhood predicts more severe anxiety-related symptoms in adolescence. Previous studies have noted that many mothers who smoke while pregnant continue to do so during the child's early years (Yolton et al., 2005), therefore it is difficult to disentangle which smoking behaviour has the most detrimental effects. Few studies have compared these exposure times but based on a study which found prenatal smoking associated with higher risk of attention-deficit/hyperactivity disorder than smoke exposure from birth to age two (Lin et al., 2021), I hypothesise that prenatal smoking will predict higher anxiety-related symptom scores. The third aim involves examining whether, and the magnitude by which respiratory illness moderates the development and severity of anxiety disorders in adolescence. Based on previous findings which suggest that presence of respiratory illness co-occurs with anxiety disorders (Meuret et al., 2020), I hypothesise that presence of a respiratory illness will increase the magnitude of the association between second-hand smoke exposure and anxiety measures.

Method

Participants

Data were obtained from the Longitudinal Study of Australian Children (LSAC), a national study which began in 2003 and involved the survey of a representative sample of 5,000 Australian children aged 4-5 (kindergarten cohort), and 5,000 newborns (birth cohort), and their families. Both cohorts are surveyed every two years, with the aim of collecting data relating to wellbeing and development in areas including health, education, and parenting (Australian Institute of Family Studies, 2021). Each data collection period is referred to as a "wave" and is numbered, and each child participant is referred to as a "study child".

This study examines the "birth cohort", utilising data from Wave 1 (2003-2004, when they were newborns), Wave 2 (2006, age 2-3), Wave 5 (2012, age 8-9) and Wave 7 (2016, age 12-13). After excluding participants for whom consequential variable data were missing, the total number of participants is 3,259.

Measures

Maternal Smoking While Pregnant

Maternal prenatal smoking was measured as an average of the number of cigarettes the study child's mother smoked daily during pregnancy, derived from her answers to the self-completed questionnaire. Values ranged from 0.17 of a cigarette to 55 cigarettes daily. Self-report of maternal smoking behaviour has been shown to be reasonably reliable, but second-hand smoke exposure is frequently underestimated (Chen et al., 2013).

Second-hand Smoke Exposure in Early Childhood

Second-hand smoke exposure was estimated using self-reported daily cigarette consumption for Parent 1 (and Parent 2 when applicable) at Wave 2 data collection (2006,

when the study child was 2-3 years old), representing the total number of cigarettes the study child may have been exposed to daily. Responses to this question were presented as ranges ("Less than 1", "1-5", "6-10", "11-20", "20+"), so these responses were coded using the median value for each range.

Presence of Respiratory Illness in Study Child

Presence of respiratory illness in the study child was measured using responses to the health-related survey questions at Wave 5 data collection (2012, when the study child was 8-9 years old). These responses were labelled "Study Child has been diagnosed with asthma", "Study Child has difficulty breathing", and "Study Child has sleep problems on four or more nights per week, due to asthma or wheezing", and were coded dichotomously, to represent that respiratory illness was present or absent.

Family History of Respiratory Illness

Family history of respiratory illness was measured using responses to the health-related survey questions at Wave 5 data collection. These responses indicated whether the study child's parents (labelled "Parent 1", "Parent 2" or "Parent Living Elsewhere") had ever had asthma, chronic bronchitis or lung problems, or lung cancer. These were coded dichotomously, to represent that respiratory illness was present or absent.

Family History of Depression and/or Anxiety

Family history of depression and/or anxiety was measured using responses to the survey question which asked the study child's parents, "Have you ever had any of the following conditions? Depression or anxiety", at Wave 5 data collection (2012). These responses were coded dichotomously, to represent that family history of depression and/or anxiety was present or absent.

Table 1
Characteristics of Participants and Second-hand Smoke Exposure

Participant Characteristic	Maternal Smoking While Pregnant[a]		Parental Smoking in Early Childhood[b]		Total
	Yes (%)	*No (%)*	*Yes (%)*	*No (%)*	*n (%)*
Biological sex					
Female	186 (5.7%)	1170 (35.9%)	245 (7.5%)	897 (27.5%)	1587 (48.7%)
Male	196 (6%)	1248 (38.3%)	259 (7.9%)	966 (29.6%)	1672 (51.3%)
Presence of respiratory illness in study child					
Yes	101 (3.1%)	598 (18.3%)	124 (3.8%)	464 (14.2%)	828 (25.4%)
No	258 (7.9%)	1771 (54.3%)	364 (11.2%)	1364 (41.9%)	2324 (71.3%)
NA (data missing)	23 (0.7%)	49 (1.5%)	16 (0.5%)	35 (1.1%)	107 (3.3%)
Family history of respiratory illness					
Yes	7 (0.2%)	18 (0.6%)	4 (0.1%)	10 (0.3%)	27 (0.8%)
No	3 (0.1%)	16 (0.5%)	3 (0.1%)	10 (0.3%)	20 (0.6%)
NA (data missing)	372 (11.4%)	2384 (73.2%)	497 (15.3%)	1843 (56.6%)	3212 (98.6%)
Family history of depression/anxiety					
Yes	8 (0.2%)	20 (0.6%)	6 (0.2%)	12 (0.4%)	30 (0.9%)
No	2 (0.1%)	14 (0.4%)	2 (0.1%)	8 (0.2%)	18 (0.6%)
NA (data missing)	372 (11.4%)	2384 (73.2%)	496 (15.2%)	1843 (56.6%)	3211 (98.5%)

[a] Data missing for 459 participants.
[b] Data missing for 892 participants.

Anxiety-related Symptoms

Strengths and Difficulties Questionnaire Emotional Symptoms Questions. The 25-item Strengths and Difficulties Questionnaire (SDQ, Goodman, 1997) is an instrument measuring competencies and potential problem behaviour in children and is considered more suitable as a screening instrument than in-depth assessment (Stone et al., 2010). It contains four items which indicate anxiety-related symptoms, “Many fears, easily scared”, “Nervous in new situations, easily loses confidence”, “Many worries or often seems worried” and “Often complains of headaches, stomach-aches or sickness”. As part of the LSAC, this

questionnaire was administered to the study child, their primary parent, and their teacher. Each question is given with the response options “Not true”, “Somewhat true” and “Certainly true”. Among children aged 11-15, sensitivity is greatest when parent, teacher and self-report questionnaires are combined (Goodman et al., 2000), so scores were converted to numerals and the scores from the study child, parent and teacher were averaged to obtain a score for each question.

Paediatric Quality of Life Inventory. The 23-item Paediatric Quality of Life Inventory (PedsQL, Varni et al., 1999) is a measure of quality of life for children and adolescents, based on health-related factors. It has been validated for use with children aged 2-18 and can be used for both healthy children and those with chronic health conditions (Varni et al., 2005). As part of the LSAC, this questionnaire was administered to the study child’s primary parent who was asked to rate how often in the past month the study child has had certain problems or troubles. Items relating to anxiety symptoms include “Problems with feeling afraid or scared”, “Trouble sleeping” and “Problems with worrying about what will happen to him/her”. Questions are given with response options “Never”, “Almost Never”, “Sometimes”, “Often”, “Almost Always”, and “Not sure”. Responses were converted to numerical scores.

Principal component analysis was used to obtain a composite measure of “anxiety”, using numerical scores from these seven items. The correlation matrix (Table 2) shows that each item is weakly to moderately correlated with each other item, suggesting an acceptable degree of shared variance. The scores derived using principal component analysis correlate with each item moderately to strongly, suggesting that the derived scores account for a decent degree of shared variance.

Table 2

Correlation Matrix for Measures Relating to Anxiety

Variable	1	2	3	4	5	6	7	8
1. SDQ[a] – "Many fears, easily scared"	—							
2. SDQ – "Nervous in new situations…"	.50**	—						
3. SDQ – "Many worries /often seems worried"	.55**	.50**	—					
4. SDQ – "Often complains of…sickness"	.30**	.23**	.36**	—				
5. PedsQL[b] – "Problems with feeling afraid…"	.52**	.32**	.42**	.25**	—			
6. PedsQL – "Trouble sleeping"	.29**	.24**	.35**	.26**	.41**	—		
7. PedsQL – "Problems with worrying about…"	.43**	.32**	.50**	.26**	.60**	.52**	—	
8. Derived "anxiety" Scores[c]	.76**	.64**	.77**	.50**	.75**	.62**	.77***	—

[a] Strengths and Difficulties Questionnaire (Goodman, 1997).

[b] Paediatric Quality of Life Inventory (Varni et al., 1999).

[c] Derived "anxiety" scores were calculated using complete observations only, *N = 3259.*

*** $p < .001$.

Results

To examine the first hypothesis, that maternal prenatal smoking, parental smoking in early childhood, biological sex, presence of respiratory illness, family history of respiratory illness, and family history of depression or anxiety would have significant influence on anxiety scores, a multiple linear regression analysis was conducted. This model ($F(6,18) = 2.68$, $p = 0.049$, adjusted $R^2 = 0.3$) appears to account for 30% of variation in anxiety scores. Results (shown in Table 3) indicate that only biological sex is a significant predictor of anxiety scores (a positive slope indicates that being female is associated with higher scores of anxiety). As data for certain variables were missing for a large proportion of participants, a second multiple linear regression analysis was conducted using only the variables maternal smoking, parental smoking, biological sex, and presence of respiratory illness as predictors. The results of this model (shown in Table 4) indicate that biological sex and presence of respiratory illness are both significant predictors of scores of anxiety, and this model ($F(4,2103) = 11.48$, $p = <0.001$, adjusted $R^2 = 0.02$) appears to account for 2% of the variance in anxiety scores.

To examine the second hypothesis, that prenatal maternal smoking would have a greater effect on adolescent anxiety scores than parental smoking in early childhood would, a one-way analysis of variance (ANOVA) was conducted to compare the mean anxiety scores between participants who were only exposed to second-hand smoke *in utero* (maternal smoking group, $n = 181$), participants who were only exposed to parental second-hand smoke in early childhood (parental smoking group, $n = 352$), and participants for whom neither parent smoked at either time (no exposure group, $n = 1746$). The results of this ANOVA indicated that there were significant differences in anxiety scores for each exposure group ($F(2,1768) = 5.83$, $p = 0.003$, $\eta^2 = 0.007$), and that .7% of the variance in anxiety scores was accounted for by group differences. The maternal smoking group ($M = 0.66$, $SD = 3.86$) had a

significantly (p = 0.002) higher mean score when compared with the parental smoking group (M = -0.48, SD = 3.31), and a significantly (p = 0.015) higher mean score when compared to the no exposure group (M = -0.12, SD = 3.69). However, the differences in means between the parental smoking group and the no exposure group were not significant (p = 0.10).

To examine the third hypothesis, that the presence of respiratory illness reported at age 8-9 would have a moderating the effect on anxiety scores in early adolescence, two moderation analyses were conducted. In participants exposed to prenatal maternal smoking (n = 2,728), maternal smoking (B = 0.06, t = 2.74, p = 0.006) and presence of respiratory illness (B = 0.45, t = 2.83, p = 0.005) showed a collective significant effect on anxiety scores in early adolescence (F(2,2725) = 8.19, p = <0.001, adjusted R^2 = 0.005) in the original linear model. When the interaction term was introduced into the model, presence of respiratory illness was not found to have a significant moderating effect (B = 0.07, t = 1.66, p = 0.098) on the relationship between maternal smoking and scores of anxiety, indicating that the interaction between maternal smoking and presence of respiratory illness does not account for a significant portion of additional variation in anxiety scores beyond that which is explained by each predicting factor (F(3,2724) = 6.38, p = <0.001, adjusted R^2 = 0.006) . In participants exposed to parental smoking in early childhood (n = 2,316), presence of respiratory illness (B = 0.42, t = 2.42, p = 0.016) showed a significant effect on anxiety scores in early adolescence in the original linear model (F(2,2313) = 3.45, p = 0.032, adjusted R^2 = 0.002), while parental smoking was not shown to be a significant predictor (B = 0.01, t = 0.99, p = 0.323) . When the interaction term was introduced into the model, presence of respiratory illness was not found to have a statistically significant moderating effect (B = -0.02, t = -.56, p = 0.065) on the relationship between parental smoking and scores of anxiety (F = (3,2312) = 2.50, p = 0.058, adjusted R^2 = 0.002), indicating that this interaction term does not account for a

significant portion of additional variation in anxiety scores beyond what is explained by each predicting factor.

Table 3
Multiple Linear Regression Model with Six Predictor Variables

Predictor Variable	*B*	*SE*	*t*	*p*
Intercept	-7.71	2.16	-3.57	.002**
Biological sex	3.74	1.42	2.63	.017*
Maternal smoking while pregnant	-0.17	0.24	-0.72	.480
Parental smoking in early childhood	-0.06	0.10	-0.65	.526
Presence of respiratory illness	0.93	1.36	0.68	.504
Family history of respiratory illness	1.52	1.31	1.16	.263
Family history of depression or anxiety	2.21	1.44	1.54	.142

n = 25

Table 4
Multiple Linear Regression Model with Four Predictor Variables

Predictor Variable	*B*	*SE*	*t*	*p*
Intercept	-1.82	0.25	-7.22	<.001***
Biological sex	1.00	0.16	6.42	<.001***
Maternal smoking while pregnant	-0.01	0.03	-0.18	.861
Parental smoking in early childhood	0.01	0.01	0.78	.438
Presence of respiratory illness	0.43	0.18	2.4	.017*

n = 2,108

Discussion

This study aimed to explore whether second-hand smoke exposure in early childhood influences the development of anxiety disorders, and whether the presence of a respiratory illness facilitates these effects. The first hypothesis asserted that prenatal maternal second-hand smoke exposure, parental smoking in early childhood, presence of a respiratory illness, family history of respiratory illness, family history of depression or anxiety, and biological sex would each have a statistically significant influence on measures of anxiety in early adolescence. The first linear model returned statistically insignificant results for most predicting factors, which may be attributable to the small sample size (n = 25) decreasing statistical power. When family history of respiratory illness and family history of depression or anxiety were removed from the model, presence of respiratory illness was shown to have a statistically significant relationship with anxiety scores, suggesting that respiratory illnesses may indeed co-occur with anxiety disorders in childhood and early adolescence in this sample (n = 2,108). These findings are consistent with findings from studies of adults, including Verberg et al. (1994) who found high prevalence of respiratory illness among participants with panic disorder than among their control group, and Goodwin et al. (2003) who found that severe asthma was associated with greater risk of an anxiety disorder. Biological sex was found to be a significant predictor in both models, which indicate that being female is associated with higher scores of anxiety. This is consistent with the findings of Ranta et al. (2006) who found that among adolescents aged 12-16, girls consistently scored higher than boys on scores of social anxiety. The fact that many of the other factors were not found to be significantly associated with anxiety scores suggests that if any associations do exist, the interactions between these (and other) factors is complex, as noted by Cabral & Patel (2020).

The second hypothesis asserted that maternal prenatal smoking would have a greater influence than parental smoking in early childhood on anxiety scores. This hypothesis was supported by the results, which found a statistically significantly higher mean anxiety score among the maternal prenatal smoking group. This finding is consistent with other studies comparing second-hand smoke exposure at these two time points, including Tiesler et al. (2011) who found that prenatal second-hand smoke exposure led to increased risk of behavioural problems (hyperactivity or inattention) at age ten than postnatal exposure, and Mackay et al. (2016) who observed a weak association between maternal prenatal smoking and hypomania in early adulthood while no association was found for participants who were exposed to paternal prenatal smoking or second-hand smoke in early childhood. In both cases maternal prenatal smoking was found to be the more detrimental source of second-hand smoke exposure in that it appeared to lead to less favourable health outcomes later in life. These results are somewhat unsurprising, as prenatal smoking has long been associated with harmful health outcomes (Ershoff et al., 1999; Kovess et al., 2015).

Parental smoking behaviour in early childhood (age 2-3) was not found to be a statistically significant predictor of anxiety scores in either linear model, and the parental smoking group was not found to be significantly different from the no exposure group in terms of mean anxiety score. This is likely due to disparity between the self-reported smoking behaviours of parents and the second-hand smoke exposure the study child may have been subject to, as an estimation of daily cigarette consumption does not consider factors such as proximity to the child while smoking, second-hand smoke exposure from a non-parent source (Chen et al., 2013) such as a relative or carer, or other forms of smoke inhalation (such as smoke from household wood fires, Bennet et al., 2010).

The third hypothesis asserted that the presence of respiratory illness at age 8-9 would have a moderating effect between second-hand smoke exposure and anxiety-related

symptoms. The results of the analysis did not demonstrate that the presence of respiratory illness had a moderating effect between second-hand smoke exposure and anxiety scores in those exposed to prenatal smoking or parental smoking, but instead suggested a small direct association between presence of respiratory illness and anxiety-related symptoms, as noted when examining the first hypothesis. This suggests that among those participants with respiratory illness who experience anxiety-related symptoms, their respiratory illness may be a small contributing factor. Because second-hand smoke exposure has been found to increase the risk of a child developing a respiratory illness (Burke et al., 2011), a directional relationship between second-hand smoke exposure, respiratory illness and anxiety may exist due to the influence of an additional common factor, and some studies suggest a biological vulnerability such as sensitivity to suffocation or carbon dioxide (Verburg et al., 1994; Craske et al., 2011), or a predisposition to catastrophising certain bodily sensations (Meuret et al., 2020).

Another factor of interest is the temporal relationship between respiratory illness and anxiety disorders. Both can develop in childhood, and previous studies note the similarity of symptoms, to the extent that panic disorder may be misdiagnosed as the respiratory illness (Craske et al., 2011). Symptoms of anxiety may present differently among children of different ages (Beesdo et al., 2009), and an individual may experience symptoms of an anxiety disorder or respiratory illness for some time before medical help is sought or a formal diagnosis is obtained, further complicating this relationship. Craske et al. (2011) found that the experience of respiratory disturbance such as wheeze or asthma at age fifteen was associated with panic disorder and/or agoraphobia at age eighteen or twenty-one when compared with healthy controls, suggesting that respiratory illness may precede the development of anxiety disorder. However, they note that diagnoses of panic disorder were not recorded before adulthood, so it was unknown how long these participants had been

experiencing their anxiety-related symptoms. Similarly, this present study notes that presence of respiratory illness at age 8-9 is associated with subsequent measures of anxiety at ages 12-13. However, measures of anxiety at or before age 8-9 may not be considered equivalent as the Strengths and Difficulties Questionnaire (Goodman, 1997), was not completed by the study child at these age groups, therefore no clear conclusions can be drawn to map the course of the associated development of respiratory illness and anxiety disorder.

This study has several additional limitations. First, measures of anxiety-related symptoms were calculated based on subscales of general wellbeing questionnaires rather than instruments specifically designed to measure anxiety-related symptoms (such as the State–Trait Anxiety Inventory for Children, Spielberger, 1973). While the principal component analysis solution was considered acceptable, a direct measure of anxiety-related symptoms would likely produce a more accurate approximation of "anxiety". Second, measures of parental smoking in early childhood were based on daily cigarette consumption as self-reported by one or both parents. A direct biological measure such as serum or salivary cotinine, a nicotine metabolite (Bandiera et al., 2011), would have produced a more accurate measure of the level of second-hand smoke exposure the child was typically subject to (Bot et al., 2013). Other limitations include the fact that presence of respiratory illness, family history of respiratory illness, and family history depression or anxiety were coded as present/absent, which does not take into consideration the severity of the illness or the length of time that the person experienced the illness. There are certain additional variables that a study of this design is unable to measure and subsequently control for, such as third-hand smoke, where chemicals and substances from cigarette smoke settle upon surfaces and remain in the environment (Protano, 2011) and present a particular danger to young children (Padrón et al., 2014). Finally, as this study was non-experimental and drew from pre-existing data, there are likely additional unidentified variables involved in these interactions which

prevent us from making direct causal inferences. Future prospective studies exploring second-hand smoke exposure, respiratory illness and anxiety symptoms should focus on employing biological measures of second-hand smoke exposure (a measure of cotinine from mothers during pregnancy, and from the children at different stages in life, eliminates the need to rely on self-report to ascertain smoking behaviour) as well as instruments which measure anxiety-related symptoms specifically. Severity and duration of symptoms of respiratory illness should also be considered a key focus, and each measure should be taken at all relevant time points.

This study highlights some key issues regarding second-hand smoke exposure among Australian children. Nearly 12% of study participants had been exposed to prenatal maternal smoking, and approximately 15% had at least one parent who smoked during their early childhood. As there is no safe level of second-hand smoke exposure (Butz et al., 2011), these children and their families are at risk from the physiological health detriments which have long been associated with smoke exposure (Lodovici & Bigagli, 2009). Findings from this and previous studies indicate that those exposed to prenatal maternal smoking are most at risk of negative health outcomes (Leung et al., 2015; Tiesler et al., 2011). Development or exacerbation of asthma and other respiratory illness is a risk for children who are exposed to any form of second-hand smoke (Burke et al., 2011; Butz et al., 2011), and respiratory illness may in turn put them at risk of mental health issues later in life including anxiety disorders (Verburg et al., 1994), as supported by findings from this present study. Children are often subjected to second-hand smoke exposure in their homes, where government smoking legislation does not apply (Sims et al., 2010), and may not have the understanding or opportunity to avoid or minimise their own exposure and resultant harmful health effects. Additionally, smoking behaviours in the household may be normalised (Holdsworth & Robinson, 2013) or modelled to children as a coping mechanism by parents experiencing

anxiety-related symptoms (Zvolensky et al., 2006), therefore these children are also at risk of adopting smoking behaviours themselves. Therefore, smoking cessation campaigns continue to be necessary measures for attempting to curb smoking behaviours (Durkin et al., 2012), and research to determine their effectiveness is needed to ensure they achieve optimal outcomes (Stewart et al., 2011). Children and adolescents may continue to face preventable health issues if they are raised in living situations where there is a danger of second-hand exposure, so actively discouraging all forms of parental smoking is an important step in tackling childhood and adolescent health issues, reducing the burden on the healthcare system (Craske et al., 2001), and improving both physical and mental health among all Australians.

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