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The associations between callous-unemotional traits and symptoms of conduct problems, hyperactivity and anxiety: A twin study

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RÉSUMÉ

Les traits d'insensibilité émotionnelle, tels le manque d'empathie, le manque de remords et l'affect superficiel, sont corrélés avec les troubles de comportement chez les jeunes. La recherche suggère que les traits d'insensibilité émotionnelle et les troubles de comportement sont influencés par des facteurs génétiques communs, et pourraient aussi être influencés, du moins en partie, par des facteurs environnementaux communs. Bien que travaux antérieurs suggèrent que les traits d'insensibilité émotionnelle soient positivement (p. ex., hyperactivité) ou négativement (p. ex., anxiété) associés à d'autres symptômes de psychopathologie, les études portant sur les facteurs étiologiques communs aux traits d'insensibilité émotionnelle et ces autres symptômes de psychopathologie sont plus limitées. **Objectifs.** Nous proposons d'examiner les associations étiologiques entre les traits d'insensibilité émotionnelle et 1) les troubles de comportement, 2) l'hyperactivité, et 3) l'anxiété, à l'aide d'un échantillon de jumeaux. **Méthode.** Les participants sont 204 paires complètes et 18 paires incomplètes de jumeaux de même sexe (n = 426; 42% filles; 43% MZ; âge = 15 ans) issus du *Child and Adolescents Twin Study in Sweden*, une étude longitudinale composée de jumeaux suédois. Des mesures auto-révélées ont été utilisées pour évaluer les traits d'insensibilité émotionnelle, les troubles de comportement, l'hyperactivité et l'anxiété. Des modèles d'équations structurelles ont été estimés afin d'évaluer les contributions génétiques et environnementales des traits d'insensibilité émotionnelle ainsi que leur chevauchement étiologique avec les troubles de comportement, l'hyperactivité et l'anxiété. **Résultats.** Nous avons trouvé une corrélation génétique forte et positive entre les traits d'insensibilité émotionnelle et les troubles de comportement, mais aucune corrélation significative sur le plan des facteurs environnementaux. Nous avons trouvé une corrélation génétique modérée entre les traits d'insensibilité émotionnelle et l'hyperactivité. Nous avons

également trouvé une corrélation génétique modeste et négative entre les traits d'insensibilité émotionnelle et l'anxiété. **Conclusion.** Ces résultats suggèrent l'existence de facteurs génétiques communs expliquant les traits d'insensibilité émotionnelle et les troubles de comportement, plus particulièrement, et dans une moindre mesure les traits d'insensibilité émotionnelle et l'hyperactivité. En outre, les résultats suggèrent que des facteurs génétiques contribuant à la présence de traits d'insensibilité émotionnelle contribueraient aussi à la diminution des symptômes d'anxiété.

Mots-clés: traits d'insensibilité émotionnelle, troubles de comportement, hyperactivité, anxiété, étude de jumeaux

ABSTRACT

Callous-unemotional (CU) traits, such as lack of empathy, lack of guilt and shallow affect, are associated with conduct problems in youth. Research suggests that CU traits and conduct problems share common genetic factors and, possibly environmental factors. Despite evidence for a behavioural association between CU traits and hyperactivity and between CU traits and low anxiety, the etiological associations between these pairs have been considerably less explored. **Objectives.** Using a twin model-fitting approach, we investigated the etiological associations between CU traits and 1) conduct problems, 2) hyperactivity and 3) anxiety. **Method.** Participants were 204 complete pairs and 18 incomplete pairs of same-sex twins (n = 426; 42% female; 43% MZ; age = 15) drawn from the Child and Adolescents Twin Study in Sweden, a longitudinal study of twins born in Sweden. CU traits, conduct problems, hyperactivity and anxiety were assessed through self-reports. Structural equation modeling was used to conduct model-fitting analyses. **Results.** We found a strong positive genetic correlation between CU traits and conduct problems but no significant environmental correlations. We found a moderate genetic correlation between CU traits and hyperactivity. We also found a modest but significant negative genetic correlation between CU traits and anxiety. **Conclusion.** These findings suggest that common genetic factors explain CU traits and conduct problems, more particularly, and to a lesser extent CU traits and hyperactivity. In addition, these findings suggest that some of the genetic factors contributing to CU traits may also contribute to decreasing levels of anxiety.

Keywords: callous-unemotional traits, conduct problems, hyperactivity, anxiety, twin study

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CHAPTER 1: INTRODUCTION

Antisocial behaviour in youth is associated with long-term repercussions, at both individual and societal levels (Frick & Dickens, 2006; Moffitt, 2003). It has been shown that youth who develop conduct problems at an early age are at an increased risk of showing a pattern of continuity to their antisocial behaviour, which persists well into late adulthood and develops in both variety and frequency (Moffitt, 1993, 2003). Their outcomes in terms of successful relationships, emotional and mental health and career prospects are more likely to be poor (Frick, Cornell, Barry, Bodin, & Dane, 2003; Moffitt, 2003). Furthermore, the economic consequences to society resulting from conduct problems in youth are high. Considering healthcare, educational, residential and judicial costs, among others, researchers have estimated that youth with severe conduct problems cost society ten times more than youth who do not present such behavioural problems (Scott, Knapp, Henderson, & Maughan, 2001).

However, it has been shown that youth with conduct problems form a heterogeneous group. Apart from the age of onset of their conduct problems, other factors have been found to be a valid way of subtyping these youth. One of these factors is the presence of callous-unemotional (CU) traits (Frick, Cornell, Bodin, et al., 2003). CU traits encompass characteristics such as lack of empathy, lack of remorse and superficial affect. Youth with combined conduct problems and CU traits have been found to be at an increased risk of police contacts (Christian, Frick, Hill, Tyler, & Frazer, 1997), violent offending (Frick, Cornell, Bodin, et al., 2003), resistance to treatment (Hawes & Dadds, 2005), problems with peers (Fontaine, McCrory, Boivin, Moffitt, & Viding, 2011), and psychopathy in adulthood (Lynam, Caspi, Moffitt, Loeber, & Stouthamer-Loeber, 2007).

Youth with CU traits have also been found to have high levels of other types of externalizing problems, notably hyperactivity (Fontaine, Barker, Salekin, & Viding, 2008). However, the association between CU traits and internalizing problems, such as anxiety, is less clear. The flat affect and unemotionality that are characteristic of youth with CU traits would tend to imply a negative, or at least negligible, correlation between CU traits and emotional distress. Although some studies have confirmed this hypothesis (Frick, Lilienfeld, Ellis, Loney, & Silverthorn, 1999), others have reported positive correlations between the two traits (Fontaine, Rijsdijk, McCrory, & Viding, 2010).

Correlations between two different traits can emerge through a number of contexts. One process that can result in behavioural correlations between two traits is through common etiological factors (Rijsdijk & Sham, 2002). An etiological factor is a genetic or environmental influence that contributes to the development (or lack thereof) of a trait or behaviour. Through twin research, it is possible to estimate the proportion of genetic and environmental contributions to the etiology of a trait or behaviour. It is also possible to estimate the etiological association between two traits/behaviours, which represents the degree to which two separate traits/behaviours share the *same* etiological factors. In other words, an etiological association indicates that this same factor contributes to two *different* traits/behaviours, which could explain the aforementioned behavioural correlations (Rijsdijk & Sham, 2002).

Past research has suggested that CU traits and conduct problems share common genetic factors and, possibly, environmental factors (Bezdjian, Tuvblad, Raine, & Baker, 2011; Blonigen, Hicks, Krueger, Patrick, & Iacono, 2005; H. Larsson et al., 2007; Viding, Frick, & Plomin, 2007). However, the etiological associations between CU traits and other

psychopathological symptoms, such as hyperactivity and anxiety, have been less explored. To address these limitations, we used a twin design in order to estimate the etiological associations between CU traits and 1) conduct problems, 2) hyperactivity and 3) anxiety.

CHAPTER 2: LITERATURE REVIEW

The following chapter presents a review of the scientific literature regarding CU traits and their associations with conduct problems, hyperactivity, and anxiety. In the first section, we focus on CU traits and their behavioural associations with conduct problems, hyperactivity and anxiety. Next, we examine research on the etiology of these four traits. Finally, we discuss the etiological associations between CU traits and symptoms of conduct problems, hyperactivity and anxiety.

Part I: CU traits and their behavioural associations with conduct problems, hyperactivity and anxiety

CU traits and conduct problems

CU traits refer to a constellation of characteristics that includes an absence of guilt, a shallow affect, and a lack of empathy and remorse (Frick, Barry, & Bodin, 2000). CU traits constitute the affective factor of psychopathy and are considered the clinical hallmark of this syndrome (Cleckley, 1976; Hare, 2003). In addition, CU traits in youth have been identified as a precursor to adult psychopathy (Lynam et al., 2007).

CU traits have also been particularly useful in subtyping antisocial behaviour in youth, as youth with conduct problems have been found to form a heterogeneous group (Frick & Dickens, 2006). For instance, Essau, Sasagawa, and Frick (2006) found that CU traits predicted problematic behaviour such as conduct disorder, aggressive and antisocial behaviour and externalizing symptoms for both boys and girls in a sample of 1,443 adolescents aged 13 to 18 years. Similarly, in a sample of 1,517 boys, CU traits were found to predict serious criminal charges and moderate to serious violence over 2 years (Pardini & Fite, 2010). As such, the

presence of CU traits appears to be important in distinguishing a specific subset of children with conduct problems who are at an increased risk of complications (Frick, Cornell, Barry, et al., 2003) due to their more severe, frequent and persistent antisocial behaviour. Indeed, youth with combined CU traits and conduct problems tend to have a higher rate and variety of antisocial behaviours and police contacts (Christian et al., 1997; Frick, Cornell, Barry, et al., 2003). This group tends to show higher levels of proactive aggression (i.e., instrumental, or used for gain) and premeditated violence (Frick, Cornell, Barry, et al., 2003; Viding, Fontaine, & McCrory, 2012). They also appear to be more resistant to treatment (Hawes & Dadds, 2005). For these reasons, CU traits have been added as a specifier (labeled 'limited prosocial emotions') to conduct disorder in the *Diagnostic and Statistical Manual of Mental Disorders – 5th edition* (American Psychiatric Association, 2013). The limited prosocial emotions specifier indicates that conduct disorder can present under two forms: with or without CU traits.

Although most studies have found strong associations between CU traits and conduct problems, the relationship appears to be asymmetrical. It has been found that children with high levels of CU traits are very likely to also have high levels of conduct problems, but that the opposite does not hold true: children with high levels of conduct problems are only moderately likely to also have high levels of CU traits (Viding et al., 2012). For instance, a longitudinal study of 9,578 youth from ages 7 to 12 years found that children with high levels of CU traits had a 95% probability of having high levels of conduct problems but that children with high levels of conduct problems only had a 50% likelihood of having high levels of CU traits (Fontaine et al., 2011).

CU traits and hyperactivity

CU traits are also associated with other externalizing behaviours, such as hyperactivity or attention deficit hyperactivity disorder (ADHD). Studies have found moderate to strong correlations between these two types of psychopathological symptoms in youth samples (Fontaine et al., 2008; Loney, Frick, Clements, Ellis, & Kerlin, 2003; Waschbusch & Willoughby, 2008). However, some research suggests that this association may be influenced by the presence of conduct problems. To support this hypothesis, studies have shown that conduct problems and hyperactivity are often comorbid. For instance, Nagin and Tremblay (2001) reported that 43-47% of youth with chronic or high-declining levels of conduct problems showed high levels of hyperactivity, as opposed to 1-16% of youth with low or moderate-declining levels of conduct problems. This study also reported that hyperactivity was the strongest predictor of high levels of physical aggression. Similarly, Pardini and Fite (2010) reported that ADHD symptoms predicted both moderate/serious violence and conduct problems.

Indeed, CU traits, conduct problems and hyperactivity often co-occur. For instance, Fontaine et al. (2011) found that youth with high levels of CU traits and conduct problems were more likely than their low-CU, low-conduct problems counterparts to also have high levels of hyperactivity. In their study of 154 children aged 6 to 13 years, Barry et al. (2000) found that 37% of youth with ADHD-only displayed high levels of CU traits as opposed to 9% of their control group. However, 57% of children with *both* ADHD and conduct problems were found to have high levels of CU traits. Similarly, Frick, Cornell, Barry, et al. (2003) found that 48% of children with combined CU traits and conduct problems also presented high levels of ADHD, as opposed to under 20% of children with only one or the other disorder. On the other hand, Loney

et al. (2003) found that although boys with combined antisocial behaviour and CU traits presented high levels of ADHD, these levels were not significantly different than those of antisocial boys *without* CU traits.

For these reasons, research has focused on the potential contribution of hyperactivity to the development of persistent conduct problems, CU traits and adult psychopathy. It has been suggested that youth with combined conduct problems and hyperactivity may represent a group that is particularly at risk of psychopathy in adulthood (Lynam, 1996). However, empirical findings tend to challenge this theory. For instance, Barry et al. (2000) found that although children with combined ADHD and conduct problems were likely to show features associated with psychopathy in adults (e.g., thrill seeking behaviours and a reward-dominant response style), it was *only* those with concurrent CU traits who exhibited these characteristics. Similarly, a longitudinal twin study of 1,480 youth found no evidence suggesting that the combination of externalizing behaviour and ADHD symptoms conferred any increased risk of psychopathic personality traits (Forsman, Larsson, Andershed, & Lichtenstein, 2007). In fact, although externalizing behaviour and, to a lesser extent, ADHD both independently predicted psychopathic personality traits, the interaction effect between the two did not. Moreover, when the psychopathic personality was split into three dimensions (Grandiose-manipulative, callous-unemotional, and impulsive-irresponsible), only externalizing behaviour predicted the callous-unemotional dimension. Neither ADHD nor the interaction effect between externalizing behaviour and ADHD significantly predicted CU traits (Forsman et al., 2007). Furthermore, in a study examining the moderating effect of hyperactivity and CU traits on the relationship between conduct problems and types of aggression, Waschbusch and Willoughby (2008) reported that the

interaction effect between CU traits and conduct problems significantly predicted proactive aggressive behaviour, a trait associated with psychopathy (Viding et al., 2012; Viding & McCrory, 2012). However, the interaction effects between CU traits and ADHD, and between CU traits, conduct problems *and* ADHD failed to reach significance in predicting proactive aggression (Waschbusch & Willoughby, 2008). In sum, although CU traits, hyperactivity and conduct problems are often comorbid, research suggests that the risk of developing psychopathy in adulthood is not any higher for youth with all three disorders than it is for youth with combined CU traits and conduct problems. Furthermore, it seems that youth with combined conduct problems and hyperactivity are not at a significant risk of adult psychopathy, as previously suggested (Lynam, 1996). Indeed, it is the presence of CU traits that appears to be the central element in determining this risk, rather than the presence of hyperactivity.

CU traits and anxiety

An association between internalizing problems, such as anxiety, and externalizing problems, such as conduct problems, has been reported in samples of adolescents (Russo & Beidel, 1994). However, the nature of the relationship between CU traits and internalizing problems is less clear. According to theory, CU traits are expected to be negatively associated with anxiety. Hervey Cleckley, who presented the first clinical description of psychopathy, included an absence of anxiety as one of its key features (Cleckley, 1941, 1976). A number of empirical studies support this negative association. For instance, in one study relying on a youth sample, CU traits were found to be negatively correlated with trait anxiety (Frick et al., 1999). Similarly, it was found that high levels of CU traits were associated with lower levels of anxiety over time in a sample of 1,517 boys (Pardini & Fite, 2010).

On the other hand, not all studies support Cleckley's theory, with some reporting no association between CU traits and anxiety. For instance, Loney et al. (2003) failed to find a significant relationship between CU traits and anxiety in their sample of 65 adolescents referred by a juvenile court. Non-significant correlations between anxiety and CU traits were also reported in a community sample of 1,359 children (Dadds, Fraser, Frost, & Hawes, 2005).

Finally, positive correlations have also been reported. In a study of 1,443 adolescents, no significant correlation between CU traits and anxiety was found in boys, but a moderate *positive* correlation was found in girls (Essau et al., 2006). Fontaine et al. (2010) also reported significantly higher levels of emotional problems, such as anxiety, in youth with high levels of CU traits as opposed to their low-CU counterparts in a longitudinal sample of 9,462 twins.

However, these discrepant findings may notably be explained by the fact that the relative importance of the presence (or lack thereof) of conduct problems in the association between CU traits and anxiety was not always explored. For instance, in the Frick et al. (1999) study mentioned above, the authors found a positive correlation between anxiety and conduct problems, and only found a negative correlation between anxiety and CU traits once they controlled this association for conduct problems. Although youth with high levels of CU traits and conduct problems showed some elevation in their anxiety levels, these levels were low *when compared* to low-CU youth with similar levels of conduct problems. In other words, for youth with the same level of conduct problems, those with high levels of CU traits showed considerably lower levels of anxiety. These findings suggest that high-CU youth may be less distressed by their problematic behaviours than low-CU youth (Frick et al., 1999).

Consistent with these findings, Andershed, Gustafson, Kerr, and Stattin (2002) categorized their sample of 1,279 adolescents into three groups: well-socialized, low-socialized and "psychopathic-like". These last two groups exhibited poor socialization (i.e., difficulties in peer relations and family functioning), but the "psychopathic-like" group also exhibited high levels of CU traits. The authors found that the "psychopathic-like" group scored significantly higher than all groups on measures of conduct problems such as violent offenses and delinquent versatility. However, they found that only the low-socialized group had significantly elevated levels of anxiety. The well-socialized group and the 'psychopathic-like' group did not differ on levels of anxiety, suggesting that the emotional stability of youth with high levels of CU traits was not affected by their poor relational functioning or their elevated levels of conduct problems. Thus, it may be that although youth with conduct problems often show high levels of anxiety, this association does not hold true for youth with *combined* CU traits and conduct problems.

Another explanation for the dissimilarity of these findings is that the heterogeneity in youth with high levels CU traits was not considered, despite evidence that these youth may significantly differ from one another, notably on their levels of anxiety (Fanti, Demetriou, & Kimonis, 2013; Kahn et al., 2013). Using the presence of anxiety symptoms to distinguish primary and secondary variants of psychopathic traits is a theory that was introduced by Karpman in 1948. The distinction between primary and secondary CU traits is based on this theory, which suggested that despite presenting the same outward manifestations (i.e., low empathy, grandiosity, manipulative behaviour, etc.), primary and secondary psychopathy (or CU traits) were the result of two different causal processes. In this model, the primary variant was expected to be associated with an inherent deficit expressed by an absence of conscience, lack of

guilt and no feeling or regard for others, whereas the secondary variant was expected to develop as a result of childhood maltreatment, inconsistent and harsh discipline, family conflicts, and rejection (Karpman, 1948; Poythress & Skeem, 2006). Anxiety levels were expected to be low in the primary group and high in the secondary group. The antisocial behaviour of the primary group was expected to be more instrumental and less violent in nature, as opposed to the more impulsive, reactional violence of the secondary group (Karpman, 1948).

Research has provided support for primary and secondary variants of CU traits in youth samples. In their sample of 2,306 adolescents, Fanti et al. (2013) identified two groups of youth with high levels of CU traits. In line with theory, the secondary group scored significantly higher on levels of anxiety, narcissism, aggression and conduct problems than the primary group. Similar results were reported in a sample of 272 adolescents, where two groups scoring high on levels of CU traits emerged and could be significantly distinguished by their levels of anxiety and past trauma (Kahn et al., 2013). Providing support to Karpman's theory, it was found that the secondary group showed higher levels of anxiety, impulsivity, externalizing problems, and aggression, and was more likely to have a history of abuse (Kahn et al., 2013). Therefore, a negative association between CU traits and anxiety would be expected in the primary variant, but a positive association would be expected in the secondary variant.

In short, although in theory CU traits are expected to be negatively associated with anxiety, conflicting results have been found in the literature (e.g. Fontaine et al., 2010; Loney et al., 2003). These inconsistent findings may be due to a failure to consider the role of conduct problems, as it may be that youth with combined CU traits and conduct problems show lower

anxiety levels than youth with only conduct problems. The lack of distinction between primary and secondary CU traits may also have produced contrasting results.

Part II: Etiology of CU traits, conduct problems, hyperactivity and anxiety

Research based on twin samples has yielded important information on the etiology of CU traits, conduct problems, hyperactivity and anxiety. Although there are many ways of exploring the etiology of a behaviour, one of the most common methods is through the use of a twin design, which is the method used in our study. This section will focus on twin studies that have investigated the etiologies of the aforementioned behaviours.

Twin studies

The purpose of twin designs is to study the relative contributions of genetic and environmental influences to individual differences in the manifestation of a particular trait or behaviour (Rijsdijk & Sham, 2002). These relative contributions or etiological factors refer to the internal causal processes that result in the manifestation of a behaviour, trait or outcome (otherwise known as a *phenotype*) (Brendgen, Vitaro, & Girard, 2012).

Twins who have been raised together present a unique opportunity to compare two people who share characteristics, but who may present different phenotypes. Twin studies compare the phenotypic similarity between identical (or monozygotic, MZ) twins and fraternal (or dizygotic, DZ) twins. They rely on the notion that individual differences can be explained by genetic, shared environmental and non-shared environmental influences (Neale & Cardon, 1992). Genetic influences stem from the impact that a person's genes have on the manifestation of a trait or behaviour. It is assumed that MZ twins share 100% of their genetic makeup whereas

DZ twins share 50% of their genetic makeup. Shared environmental influences are environmental elements that impact both twins to the same extent and that increase the similarity between them (e.g. socio-economic status, neighbourhood characteristics, etc.). Non-shared environmental influences are elements that are experienced differently by each twin and that decrease the similarity between them (e.g., peer relationships, experience of abuse, etc.). Any resemblance between twins can therefore be due to either genetic or shared environmental influences whereas any differences are due to non-shared environmental influences. Twin studies thus estimate the contributions of the different sources of variance (i.e., genetic, shared environmental and non-shared environmental) to the phenotypic differences in twin pairs.

In this report, the degree of etiological contributions to a behaviour will be considered in four broad categories: low, modest, moderate and strong influences. This classification is based on a number of etiological studies on CU traits and their associated behaviours. An outline of this classification can be found in Table 1.

Table 1. Degree of etiological contributions to CU traits

Degree of etiological contribution	Etiological contribution in %	Reviewed studies
Weak *or low, minimal, negligible, little*	0 – 10%	(H. Larsson, Andershed, & Lichtenstein, 2006; Viding, Blair, Moffitt, & Plomin, 2005; Viding et al., 2007)
Modest	11% – 30%	(Henry, Pingault, Boivin, Rijsdijk, & Viding, 2016; Saudino, Ronald, & Plomin, 2005; Viding et al., 2005)
Moderate	31% – 50%	(Blonigen et al., 2005; Henry et al., 2016; H. Larsson et al., 2007; Taylor, Loney, Bobadilla, Iacono, & McGue, 2003; Viding et al., 2005)
Strong *or high, considerable, substantial*	60% and up	(Blonigen et al., 2005; Fontaine et al., 2010; Henry et al., 2016; Kerekes et al., 2014; H. Larsson, Andershed, et al., 2006; Taylor et al., 2003; Viding et al., 2005; Viding et al., 2007)

Etiology of CU traits

Findings from twin studies in youth samples have reported strong genetic contributions to the variance in CU traits. For instance, in the Twins Early Development Study (TEDS), genetic contributions to the variance in CU traits ranging from 58% in a mixed (i.e. boys and girls) sample of 16-year-olds (Henry et al., 2016), to 67% in a mixed sample of 7 year-olds (Viding et al., 2005), and to 67 to 78% in samples of male pre-adolescents (Fontaine et al., 2010; Viding et al., 2007). However, studies drawn from the Twin Study of Child and Adolescent Development (TCHAD) reported lower genetic contributions to CU traits. Notably, genetic contributions of 30% to 43% to the variance in CU traits were reported in adolescent samples (H. Larsson, Andershed, et al., 2006; H. Larsson et al., 2007). Two TEDS studies also reported a lower genetic contribution in girls, ranging from 0% (Fontaine et al., 2010) to 48% (Viding et al.,

2007).These findings highlight the importance of genetic contributions to the etiology of CU traits, and lower genetic contributions may point to a higher proportion of youth with secondary CU traits, whose CU levels may stem from environmental influences such as neglect rather than genetic influences.

Other studies not focusing precisely on CU traits but rather on the affective-interpersonal factor of psychopathy reported moderate genetic influences. The differences between studies focusing on the more specific measure of CU traits as opposed to those examining the more general notion of affective-interpersonal traits may have contributed to a wider variability in reported genetic contributions. In adolescent samples drawn from the Minnesota Twin Family Study (MTFS), genetic contributions of 45% and 42% were found, respectively, for measures of "fearless dominance", which included traits such as fearlessness and social potency (Blonigen et al., 2005), and "detachment", which included traits such as callousness and superficial affect (Taylor et al., 2003). A similar genetic contribution of 42% to "callousness" was reported in a twin study of 535 13- to 21-year-olds (Mann, Briley, Tucker-Drob, & Harden, 2015). These studies support the aforesaid findings on the etiology of CU traits, as they suggest an important genetic contribution to the etiology of affective and interpersonal dimensions of psychopathic traits, which include CU traits.

All studies reported significant non-shared environmental contributions, ranging from modest (16%; Henry et al., 2016) to strong (70%; H. Larsson et al., 2007). Furthermore, a number of studies reported no evidence of shared environmental influences (Blonigen et al., 2005; H. Larsson, Andershed, et al., 2006; H. Larsson et al., 2007; Mann et al., 2015; Taylor et al., 2003). On the other hand, studies drawn from the TEDS data reported minimal (6%; Viding

et al., 2005) to modest (26%; Henry et al., 2015) shared environmental contributions to CU traits. Other studies reported strong (75%; Fontaine et al., 2010) to modest (20%; Viding et al., 2007) shared environmental influences in girls. Differences in the age of the sample participants may explain some of this variability. Most of the studies reporting shared environmental influences used younger samples (e.g. 7 years old; Viding et al., 2005), whereas studies reporting no such influences used adolescent samples (e.g. 17 years old; Blonigen et al., 2005). Furthermore, the instruments used to measure CU traits varied from study to study, which may account for some of the variability in etiological influences.

In sum, CU traits appear to be highly influenced by genetic and non-shared environmental factors. Although most studies point to negligible shared environmental influences, there is some evidence that they may be especially important for a small subset of girls with stable and high levels of CU traits (Fontaine et al., 2010; Viding et al., 2007).

Etiology of conduct problems

Like CU traits, research suggests moderate to strong genetic contributions to the variance in conduct problems in youth. Genetic influences were found to contribute to 47% of the variance in conduct problems in a sample of 2,082 5- to 17-year olds according to a study drawn from the Greater Manchester twin register (Thapar, Harrington, & McGuffin, 2001). Similar results were found in two samples of 7-year-old twins drawn from the TEDS, which revealed genetic contributions ranging from 57% to 65% (Saudino et al., 2005; Viding et al., 2007). In line with these findings, Kerekes et al. (2014) reported a genetic contribution of 67% to the variance in conduct problems in their sample of 9- and 12- year old boys drawn from the CATSS

(Child and Adolescent Twin study in Sweden). However, in this study, a significantly lower genetic contribution was found for girls (26%; Kerekes et al., 2014).

In many studies, the measure of conduct problems tends to include norm-breaking behaviours, such as lying, cheating, and fighting, and low level delinquency, such as bullying and stealing (Kerekes et al., 2014; Saudino et al., 2005; Viding et al., 2007). More serious forms of delinquency/criminality, such as assault, breaking and entering, the selling and using of drugs, robbery, and arson, are often grouped under the broader category of "antisocial behaviour" (Blonigen et al., 2005; Forsman, Lichtenstein, Andershed, & Larsson, 2010; H. Larsson et al., 2007). Studies that have examined the etiology of antisocial behaviour have reported more moderate genetic influences than those found in studies on conduct problems. For instance, in a sample of 19- and 20-year-old twins drawn from the TCHAD, Forsman et al. (2010) found that 35% of the variance in antisocial behaviour was explained by genetic influences. In another TCHAD-based study, genetic contributions to antisocial behaviour ranged from 19% to 31% for boys, and from 41% to 62% for girls (H. Larsson et al., 2007).

All studies reported significant non-shared environmental influences, ranging from modest (17%; Thapar et al., 2001) to relatively strong (56%; Forsman et al., 2010). A number of studies from multiple databases reported low (0 – 13%) shared environmental contributions (Blonigen et al., 2005; Forsman et al., 2010; Saudino et al., 2005; Viding et al., 2007). However, other studies reported modest to moderate shared environmental contributions. For instance, Thapar et al. (2001) found that 36% of the variance in conduct problems was explained by shared environmental influences. A TCHAD-based study also reported similar shared environmental contributions, although these were stronger for boys (28 – 46%) than for girls (10

– 27%) (H. Larsson et al., 2007). Kerekes et al. (2014) also found a modest shared environmental influence, but only in girls (25%).

In sum, there is evidence for moderate to strong genetic contributions to the variance in conduct problems, although these findings vary. Conduct problems are also influenced by non-shared environmental factors, although the strength of these influences fluctuates. The etiological contribution of the shared environment appears to be low to moderate, and may depend on sex.

Etiology of hyperactivity

Research suggests that hyperactivity in youth is highly influenced by genetic factors. In a meta-analysis of 18 twin studies, Biederman (2005) reported that ADHD (or hyperactivity) was under strong heritability (mean of 77%). A study by Thapar et al. (2001), included in the previously mentioned meta-analysis, reported a genetic contribution of 80% to the variance in ADHD. Studies not included in this meta-analysis present similar findings. For instance, in their CATSS sample of 9- and 12-year-olds, Kerekes et al. (2014) found that genetic influences explained 61% to 67% of the variance in ADHD. Similar results were found in a TEDS sample of 7-year-olds, with one study reporting genetic contributions of 75% to 77% (Saudino et al., 2005).

Results in line with these findings were also reported in adolescent samples. H. Larsson, Lichtenstein, and Larsson (2006) found that 64% to 66% of the variance in ADHD was attributed to genetic influences in a TCHAD sample of 16- and 17- year-olds. In their Young Twins Study sample of 13- and 14-year-olds, J. O. Larsson, Larsson, and Lichtenstein (2004) also reported important genetic influences, although these were stronger for boys (74%) than for girls (61%).

All studies reported modest to moderate significant non-shared environmental contributions, ranging from 20% (Thapar et al., 2001) to 39% (Kerekes et al., 2014; J. O. Larsson et al., 2004). Although one study reported negligible shared environmental contributions to the variance in hyperactivity (2 – 3%; J.O. Larsson et al., 2004), a number of studies reported no evidence of shared environmental influences (Kerekes et al., 2014; H. Larsson, Lichtenstein, et al., 2006; Saudino et al., 2005; Thapar et al., 2001).

In sum, ADHD appears to be highly influenced by genetic factors, in both boys and girls. Environmental factors, and in particular non-shared environmental factors, explained a small to moderate part of the variance in ADHD.

Etiology of anxiety

Genetic contributions appear to explain a moderate amount of the variance in anxiety in youth. Findings from a longitudinal study evaluating the etiology of anxiety in 1,672 twins at five time points from age 7 to 20 suggested that genetic factors explained 27% to 41% of the variance (Brown et al., 2014). In a twin study of 535 adolescents, Mann et al. (2015) found that heritability contributed to 22% of the variance in "neuroticism", which included items tapping anxiety, worry and depressive affect. Other studies also reported moderate genetic contributions to anxiety (35 – 41%, Saudino et al., 2005) and internalizing problems, which included major depression, social phobia and simple phobia (31 – 49%; Blonigen et al., 2005). One study reported slightly stronger genetic contributions to anxiety (52 – 76%) in a sample of 1,412 twins aged 8 to 16 (Eaves et al., 1997).

A moderate to strong amount of the variance in anxiety has been attributed to the non-shared environment, ranging from 41% (Saudino et al., 2005) to 78% (Mann et al., 2015). The shared environment appears to influence the etiology of anxiety in low (0 – 8%; Brown et al., 2014) to modest amounts (18 – 22%; Saudino et al., 2005). One study also reported moderate shared environmental contributions to anxiety in boys (33%), but found weak contributions in girls (8%; Eaves et al., 1997). Still other studies reported no evidence of shared environmental contributions (Blonigen et al., 2005; Mann et al., 2015).

In sum, genetic factors appear to moderately explain the variance in anxiety. There is conflicting evidence for shared environmental contributions to the variance in anxiety, although the shared environment may affect males slightly more. Non-shared environmental contributions strongly influenced the etiology of anxiety across all studies.

Part III: Etiological associations between CU traits and symptoms of conduct problems, hyperactivity, and anxiety

The following section will review studies that have examined the etiological associations between CU traits and symptoms of conduct problems, hyperactivity, and anxiety. Etiological associations between behaviours refer to the degree to which the genetic or environmental factors that contribute to the etiology of one phenotype also contribute to another phenotype (Brendgen et al., 2012). For instance, if *the same* genetic factors were to influence *both* CU traits *and* conduct problems, a genetic correlation between the two behaviours could be found. The same holds true for shared environmental and non-shared environmental factors and correlations. This indicates that the etiology of both behaviours overlap in some way. This overlap can be

small, modest, moderate or strong. The classification of the degree of etiological contributions to CU traits (see Table 1) will also be used in the following section.

Association between CU traits and conduct problems

A number of studies have examined the etiological association between CU traits and conduct problems, as displayed in Table 2. All studies reported significant genetic correlations, but the strength of these correlations varied widely. The strongest correlations (.71 for boys and .77 for girls) were found between measures of CU traits and conduct problems in a TEDS sample of 7 year-olds (Viding et al., 2007). These results suggest that some of the genetic factors that influence CU traits also influence conduct problems. This is in line with a study drawn from the Southern California Twin Project (SCTP) on the genetic correlation between callous and disinhibited traits and different types of aggression (Bezdjian et al., 2011). In a sample of 1,219 9- and 10-year-old twins, a genetic correlation of .59 was found for the association between CU traits and reactive aggression, and a genetic correlation of .76 was found between CU traits and proactive aggression (Bezdjian et al., 2011). This supports findings suggesting that instrumental violence is associated with CU traits (Frick, Cornell, Barry, et al., 2003), and indicates that both behaviours may be genetically associated.

The lowest correlations (.36 for boys and .01 for girls) were found between measures of "fearless dominance", used to represent the interpersonal-affective factor of psychopathy, and externalizing problems, such as conduct disorder and drug dependence, in an MTFS sample of 16- and 17-year-olds (Blonigen et al., 2005). These findings not only challenge the sex differences (or lack thereof) noted above (Viding et al., 2007), but also suggest that the development of CU traits and of conduct problems in girls may stem from independent genetic

origins. However, this notion is directly opposed by the findings from H. Larsson et al. (2007), who reported moderate to strong genetic correlations between CU traits and antisocial behaviour (e.g. vandalism, assault, robbery) for girls (.38 at age 13-14 and .64 at age 16-17), but non-significant genetic correlations for boys of the same age groups, indicating that in that sample, it is rather in *boys* that these behaviours find independent genetic origins.

As displayed in Table 2, none of these studies reported significant shared environmental correlations. This is consistent with the aforementioned findings suggesting weak to absent shared environmental contributions to both of the phenotypes (Forsman et al., 2010; Mann et al., 2015). However, some studies reported modest to moderate non-shared environmental correlations. Bezdjian et al. (2011) found a non-shared environmental correlation of .37 between callous and disinhibited traits and reactive aggression, and of .30 for proactive aggression. More modest associations were reported by Viding et al. (2007), who found non-shared environmental correlations between CU traits and conduct problems of .19 boys and .14 for girls. These findings indicate a modest to moderate non-shared environmental etiological association between CU traits and conduct problems.

In short, there is evidence for a genetic etiological association between CU traits and conduct problems, although the findings on the degree of this association vary widely. Nonetheless, this suggests that the same genetic factors may lead to the development of two separate but strongly associated behaviours. Furthermore, whereas there was no evidence for a shared environmental association, there was some evidence for a modest to moderate non-shared environmental association between CU traits and conduct problems (Bezdjian et al., 2011;

Viding et al., 2007). This indicates that the same non-shared environmental factors may also shape the development of both phenotypes.

Table 2. Review of studies examining the etiological associations between CU traits and conduct problems

Authors	Sample	Measure of CU traits	Measure of conduct problems	r_A	r_C	r_E
Bezdjian et al. (2011)	SCTP 1,219 twins Age 9-10	Callous & disinhibited traits (CPS)	Reactive and proactive aggression (*Reactive & Proactive Aggression questionnaire*)	**Reactive** .59 **Proactive** .76	NR	**Reactive** .37 **Proactive** .30
Blonigen et al. (2005)	MTFS 626 twins Age 16-17	Fearless Dominance (MPQ)	Externalizing problems *(DSM-III-R interview*)	.36 (boys) .01 (girls) .16 (total)	NR	NR
H. Larsson et al. (2007)	TCHAD 1,480 twins Age 13-14 and 16-17	CU traits (YPI)	Antisocial behaviour (*self-report delinquency questionnaire*)	**Age 13-14** NS (boys) .38 (girls) **Age 16-17** NS (boys) .64 (girls)	NR	NR
Viding et al. (2007)	TEDS 3,434 twin Age 7	CU traits *(combination of APSD and SDQ)*	Conduct problems *(SDQ)*	.71 (boys) .77 (girls)	NS	.19 (boys) .14 (girls)

Notes.
CU = callous-unemotional; r_A, r_C, r_E = etiological correlations; NR = Not reported; NS = non-significant; SCTP = Southern California Twin Project; MTFS = Minnesota Twin Family Study; TCHAD = Twin Study of Child and Adolescent Development; TEDS = Twins Early Development Study; CPS = Child Psychopathy Scale; MPQ = Multidimensional Personality Questionnaire; DSM-III-R = Diagnostic and Statistical Manual of Mental Disorder, version 3, revised; YPI = Youth Psychopath traits Inventory; APSD = Antisocial Process Screening Device; SDQ = Strengths and Difficulties Questionnaire

Association between CU traits and hyperactivity

To our knowledge, there are no published studies on the etiological association between CU traits and hyperactivity. However, in a study of 1,480 adolescent twins drawn from the TCHAD, Forsman et al. (2007) tested whether symptoms of ADHD were associated with different dimensions of psychopathic traits, including CU traits. Although they found that CU traits and ADHD were modestly associated at the behavioural level, they did not examine whether this association was explained by genetic, shared or non-shared environmental factors.

Given the moderate to strong phenotypic association between CU traits and hyperactivity found in many studies (Fontaine et al., 2008; Waschbusch & Willoughby, 2008), and the fact that the etiology of both phenotypes is strongly influenced by genetic factors (Biederman, 2005; Henry et al., 2016), there is a need to further the understanding on the etiological association between the two phenotypes.

Association between CU traits and anxiety

The genetic correlation between fearless dominance, a phenotype similar to CU traits tapping items such as fearlessness and social potency, and internalizing problems, which included items tapping depression and phobia, was examined in a study of 16- and 17-year-old twins drawn from the MTFS (Blonigen et al., 2005). This study reported a moderate negative genetic correlation between fearless dominance and internalizing problems, indicating that the genetic factors contributing to one phenotype also contribute to *reduced* levels of the other phenotype. To our knowledge, this is the only study published that has focused on the etiological

association between psychopathic traits and internalizing problems. We found no published studies on the etiological association between CU traits and anxiety more specifically.

Part IV: The current study

Few studies have investigated the etiological associations between CU traits and various psychopathological symptoms, except for conduct problems. Those that examined the etiological association between CU traits and conduct problems reported genetic correlations as low as .01 (Blonigen et al., 2005) and as strong as .77 (Viding et al., 2007). Some studies found environmental correlations (Bezdjian et al., 2011; Viding et al., 2007), whereas others did not report such evidence (Blonigen et al., 2005; H. Larsson et al., 2007). Furthermore, the lack of studies on the etiological associations between CU traits and psychopathological symptoms other than conduct problems appears to be an important research gap.

The current study, using a twin model-fitting approach, aims to examine the etiological associations between CU traits and 1) conduct problems, 2) hyperactivity and 3) anxiety. We expect to replicate findings on the genetic and non-shared environmental etiological associations between CU traits and conduct problems. We also aim to extend research by investigating the etiological associations between CU traits and hyperactivity, and CU traits and anxiety. Although no published study has examined the etiological association between CU traits and hyperactivity, we expect to find a genetic correlation between the two phenotypes, although to a lesser magnitude than the etiological association between CU traits and conduct problems. Similar to the findings from Blonigen et al. (2005), we expect to find a negative genetic correlation between CU traits and anxiety.

The results of our study may help to explain the etiological processes involved in the simultaneous manifestation of CU traits and other psychopathological symptoms. This could lead to practical implications, notably by identifying sources of environmental influences (i.e., shared and/or non-shared environmental influences) that could be targeted in prevention and treatment programs.

CHAPTER 3: METHODOLOGY

Participants: CATSS & DOGSS

The participants were drawn from the Developmental Outcomes in a Genetic Twin Study in Sweden (DOGSS), a subsample of the larger Child and Adolescent Twin Study in Sweden (CATSS). Launched in 2004, the CATSS is an ongoing longitudinal twin study targeting all twins born in Sweden since July 1, 1992 (Anckarsäter et al., 2011). The general aim of the CATSS is to evaluate the role that neurodevelopmental problems (defined as ADHD, autism spectrum disorders, tic disorders, developmental coordination disorder, and learning disorders) play in the development of mental health problems and psychosocial maladaptation in youth. As of January 2010, the study included 17,220 children, representing roughly 80% of all twins born in Sweden since July 1992 (Anckarsäter et al., 2011).

As seen in Figure 1, at age 9 or 12, CATSS twins were screened for different developmental problems, including ADHD, autism spectrum disorders, oppositional defiant disorder, conduct disorder, obsessive compulsive disorder and eating problems (Anckarsäter et al., 2011). This was accomplished via telephone interviews with the twins' parents in which trained interviewers administered the Autism – Tics, ADHD and Other Comorbidities Inventory (A-TAC). The A-TAC contains over 250 items that are categorized into 19 modules tapping various psychiatric issues. It is specifically designed to be used over the phone, by interviewers, in large-scale epidemiological research, and is used to assess all major clinical diagnostic criteria in child and adolescent psychiatry (Anckarsäter et al., 2011). Twins whose scores were above the corresponding cut-off according to the various modules of the A-TAC were considered 'screen-positive'. These families, as well as randomly selected control families, then received follow-up questionnaires in order to gather background information relevant to the twins' physical and

mental health, such as details about their psychosocial environment, personality and peer relations (Anckarsäter et al., 2011).

Then, when the twins turned 15 years old, same-sex twin pairs for whom one or both twins had screened positive on the A-TAC, as well as random control twin pairs, were invited to be part of the CATSS-15/DOGSS data collection (Anckarsäter et al., 2011). All consenting families underwent a clinical examination led by psychologists in which each twin and their parents were evaluated separately. These clinical examinations were designed to provide a comprehensive psychiatric assessment of each participant, as well as an evaluation of their cognitive function and somatic health. Self-report questionnaires on outcomes, risk factors, and a variety of physical and mental health subjects (e.g. callous-unemotional traits) were also completed by both twins (Anckarsäter et al., 2011).

In total, 451 same-sex twins from the CATSS-15/DOGSS, including 49 control twin participants, were considered in the current study. Those who had been diagnosed with epilepsy, brain damage, chromosomal aberrations or intellectual disability (n = 25) were subsequently excluded from the analyses. As noted in Figure 1, in the end, 426 twins aged 15 years old were included in our final sample. This included 204 complete pairs, of which 24 were control participants, and 18 incomplete pairs, of which 1 was a control participant. Incomplete pairs indicate that the data at 15 years old were only available for one twin. In total, 38% of mothers and 21% of fathers had earned a university degree. The final sample consisted of 43.4% monozygotic (MZ) twins (n = 185 twins; 79 female) and 56.6% dizygotic (DZ) twins (n = 241; 97 female).

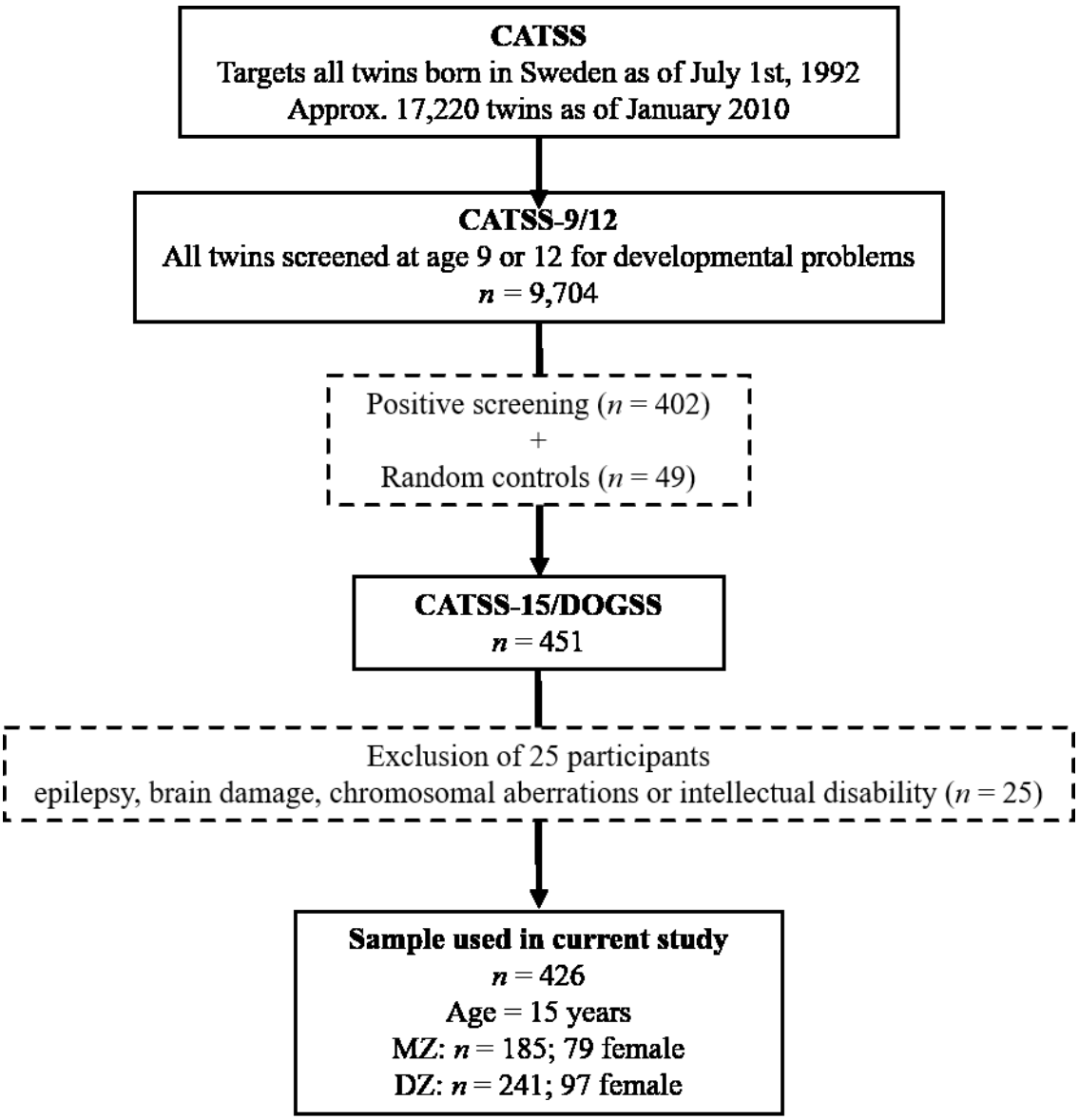

Figure 1. Organigram depicting the CATSS, CATSS-9/12, CATSS-15/DOGSS, and current study samples.

For the most part, DNA analysis established the zygosity of the twin pairs. For twins for whom DNA samples could not be provided, an algorithm based on five questions on twin similarity was used. Zygosity was only assigned through the algorithm method if the test

achieved a 95% probability of producing a correct categorization (Anckarsäter et al., 2011). The study and consent procedure were approved by the Karolinska Institute Ethical Review Board.

Measures

CU traits

CU traits were evaluated through the CU dimension scale of the self-report version of the Youth Psychopathic traits Inventory (YPI; Andershed, Kerr, Statin & Levander, 2002). The YPI was specifically designed as a self-report measure to be used in a general population of youth aged 12 and up. As deceit, lying and lack of insight are core symptoms of psychopathy, the authors purposefully developed items that overcame these issues (Andershed, Kerr, et al., 2002). For instance, the YPI frames psychopathic features as abilities ("*I have the ability not to feel guilt and regret about things that I think other people would feel guilty about*"*)* and the items are designed in a way that people with psychopathic traits would see as positive, but that others would not ("*To feel guilt and regret when you have done something wrong is a waste of time*") (Andershed, Kerr, et al., 2002).

The YPI contains 10 different subscales tapping core personality traits associated with psychopathy: Dishonest charm, Grandiosity, Lying, Manipulation, Callousness, Unemotionality, Remorselessness, Impulsivity, Thrill-seeking and Irresponsibility (Andershed, Kerr, et al., 2002). Each of these subscales contains five items that were found to evaluate the trait as reliably and as broadly as possible. Factor analyses conducted on these ten subscales revealed that a three-factor structure best fit the data, highlighting the interpersonal, affective and behavioural dimensions of psychopathy. The interpersonal *Grandiose-manipulative* dimension includes the dishonest

charm, lying, grandiosity and manipulation subscales; the affective *Callous-unemotional* dimension includes the callousness, unemotionality, and remorselessness subscales; and the behavioural *Impulsive-irresponsible* dimension includes the impulsivity, irresponsibility and thrill-seeking subscales (Andershed, Kerr, et al., 2002).

We focused on the CU dimension of the YPI because CU traits are considered the clinical hallmark of psychopathy (Cleckley, 1976; Hare, 2003). The items included in the CU dimension scale are displayed in Table 3 (Andershed, Kerr, et al., 2002). Participants rated the degree to which the item applied to them using a 4-point scale with responses ranging from "*Does not apply at all*" to "*Applies very well*" (Andershed, Kerr, et al., 2002). The internal consistency (Cronbach's alpha) for this scale was .80. The YPI was originally created by a Swedish research team for Swedish participants. In this study, it was administered in its original language, for which it has shown good reliability and validity (Andershed, Gustafson, et al., 2002). The YPI has also demonstrated good construct validity in non-Swedish samples of adolescents (Neumann & Pardini, 2014; Poythress, Dembo, Wareham, & Greenbaum, 2006).

Table 3. Items on the three subscales in the CU dimension of the YPI

Subscale	Item
Callousness	When other people have problems, it is often their own fault, therefore, one should not help them. I think that crying is a sign of weakness, even if no one sees you. I often become sad or moved by watching sad things on TV or film (r). I usually become sad when I see other people crying or being sad (r). It's important to me not to hurt other people's feelings (r).
Unemotionality	What scares others usually doesn't scare me. I usually feel calm when other people are scared. I don't understand how people can be touched enough to cry by looking at things on TV or movie. I don't let my feelings affect me as much as other people's feelings seem to affect them. To be nervous and worried is a sign of weakness.
Remorselessness	I have the ability not to feel guilt and regret about things that I think other people would feel guilty about. When someone finds out about something that I've done wrong, I feel more angry than guilty. To feel guilty and remorseful about things you have done that have hurt other people is a sign of weakness. To feel guilt and regret when you have done something wrong is a waste of time. I seldom regret things I do, even if other people feel that they are wrong.

Note.
r: reverse scored.

Conduct problems, hyperactivity and anxiety

Conduct problems, hyperactivity and anxiety were respectively assessed using the *conduct problems*, *hyperactivity* and *emotional symptoms* scales of the self-report version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, Meltzer & Bailey, 1998). The self-report SDQ is designed to be used by youth aged 11 to 16 years (Goodman, 2001) and is based on the informant-report SDQ (Goodman, 1997). Apart from changing the perspective from third person to first person, the self-report SDQ was slightly modified in order to be used by

teenagers: some of the wording was considered too childish and was adapted for older participants (Goodman et al., 1998). For instance, "*Often has temper tantrums or hot tempers*" was changed to "*I get very angry and lose my temper*". It was also designed to encourage honesty by making items seem less accusatory. For instance, "*Often lies or cheats*" was changed to "*I am often accused of lying or cheating*" (Goodman et al., 1998).

The items included in each of the SDQ scales used in this study are presented in Table 4. Participants marked each item using a 3-point scale ("*Not true", "Somewhat true"* or *"Certainly true"*) (Goodman et al., 1998). Cronbach's alphas for conduct problems, hyperactivity and anxiety were .49, .75 and .72, respectively. The relatively low internal consistency is not unusual for the Conduct problems scale, as many studies reported similar alphas (e.g., ranging from .44 to .59; Van Roy, Veenstra, & Clench-Aas, 2008).

Table 4. Items on conduct problems, hyperactivity and anxiety scales of SDQ

Scale	Item
Conduct problems	I get very angry and often lose my temper.
	I usually do as I am told. (r)
	I fight a lot. I can make other people do what I want.
	I am often accused of lying or cheating.
	I take things that are not mine from home, school or elsewhere.
Hyperactivity	I am restless, I cannot stay still for long.
	I am constantly fidgeting or squirming.
	I am easily distracted, I find it difficult to concentrate.
	I think before I do things. (r)
	I finish the work I'm doing. My attention is good. (r)
Emotional symptoms	I get a lot of headaches, stomach-aches or sickness.
	I worry a lot.
	I am often unhappy, down-hearted or tearful.
	I am nervous in new situations. I easily lose confidence.
	I have many fears. I am easily scared.

Note.
r: reverse scored.

Nevertheless, the SDQ is an established screening instrument with well-confirmed validity and reliability (Goodman, 2001). The Swedish version of the SDQ, which was used in this study, has also demonstrated good reliability and validity. For instance, a psychometric evaluation of the SDQ found satisfactory internal consistency for the various scales, with Cronbach's alphas ranging from .67 to .87, with the exception of the Conduct problems scale, for which an alpha of .52 was found (Malmberg, Rydell, & Smedje, 2003). In another study, Smedje, Broman, Hetta, and von Knorring (1999) found that factor analyses confirmed the subscale structure of the Swedish version of the SDQ, with the exception of one item on the Emotional symptoms scale ("*Often complains of headaches, stomachaches or sickness*") for boys only. Furthermore, analyses performed by Malmberg et al. (2003) indicated that all scales in the Swedish version significantly distinguished between community and clinical samples.

Data analyses

Main principles of the twin design

The current study relied on a twin model-fitting approach. The cornerstone of twin studies is the use of statistical variance. Variance is a measure that indicates the overall sample's deviation from the mean for a specific phenotype (Rijsdijk & Sham, 2002). The greater the variance, the more the measure of the phenotype varies between individuals. In twin studies, phenotypic differences can be explained by three main sources of variance: genetic, shared environmental and non-shared environmental factors (Brendgen et al., 2012; Neale & Cardon, 1992). Genetic factors, represented by the letter A, consist of the effect that genes play in the development of a trait. The shared environment, or C, refers to the environmental effects that influence both twins simultaneously and make them similar to each other (e.g., parental socio-economic status, neighbourhood characteristics, etc.). Non-shared environmental factors, or E, encompass all experiences, within or outside the family, that are unique to each twin (e.g., peer relations, abuse, etc.). These factors make the twins different from one another. E also includes all measurement error (Brendgen et al., 2012).

To elucidate the sources of variance that influence the manifestation of a given phenotype, twin studies compare the phenotypic correlations between MZ twins and between DZ twins (Neale & Cardon, 1992; Rijsdijk & Sham, 2002). Both twins are more likely to present the trait or behaviour in equal amounts when their intra-pair (MZ or DZ) correlation is high. This shared manifestation can be attributed to either genetic or shared environmental influences. A genetic (A) influence can be inferred when MZ twins, who share 100% of their genes, are more similar to each other than DZ twins, who share 50%. The intra-pair correlation for MZ twins will be

approximately double the DZ intra-pair correlation. When DZ twins are more similar than expected by genetic relatedness (i.e. the MZ intra-pair correlation is less than double the DZ intra-pair correlation), a shared environmental (C) influence can be inferred. A strong non-shared environmental (E) contribution can be found when both MZ and DZ intra-pair correlations are relatively low (Brendgen et al., 2012). The sum of these etiological contributions is equal to the total phenotypic variance (A + C + E = V) (Rijsdijk & Sham, 2002).

In order to proceed with analyses, twin studies rely on a number of assumptions. First, it is assumed that twins are representative of the general population and can be compared to singletons in terms of the manifestation of the phenotype (Brendgen et al., 2012; Rijsdijk & Sham, 2002). Second, the twin design relies on the assumption that MZ twins share 100% of their genes and that DZ twins share 50% of their genes. Third, it is assumed that both MZ and DZ twins share their environments to the same extent and that these environments influence them in the same way. For instance, it is assumed that others (e.g., parents, teachers, etc.) treat MZ twins the same way they do DZ twins. Fourth, mating is assumed to occur at random. In other words, parents are not expected to have chosen partners specifically due to their similar genotype, which could lead to DZ twins sharing more than 50% of their genes and biasing the estimations. Finally, the classic twin study relies on the assumption that genetic and environmental influences are independent of each other (Brendgen et al., 2012; Rijsdijk & Sham, 2002). Indeed, twin studies do not specifically examine interaction or correlation effects between a person's genes and their environment. Gene-environment interactions are found when the effect of genetic factors depend on environmental factors (or vice versa; e.g., a child's genetic predisposition to obesity may be stimulated by aspects of their environment, such as limited

access to physical activity) (Brendgen et al., 2012). One way that gene-environmental correlations can occur is when a person's genetic factors influence the type of environment they will experience (e.g., a child's genetic predisposition to antisocial behaviour influences their parents' negative parenting practices, which in turn increase the child's antisocial behaviour) (Brendgen et al., 2012).

Bivariate analysis of variance

The aim of the current study was to assess the proportion of etiological association between CU traits and the three other phenotypes (i.e. conduct problems, hyperactivity and anxiety). Etiological association is estimated through bivariate analyses, which measure the genetic and environmental contributions to the covariance between two phenotypes (Rijsdijk & Sham, 2002). Covariance is a statistical measure that indicates how much two phenotypes vary together from their means; it is a measure of the strength of the correlation of their variances (Weisstein, 2016). In other words, when one phenotype's higher measures correspond to the other phenotype's higher measures, and this also holds true for its lower measures, they have a strong, positive covariance; that is, the phenotypes vary together in the same direction. When the covariance is strong but negative, the phenotypes vary together in divergent directions. Both these scenarios imply that the phenotypes share etiological factors; that there exists an etiological association between the two (Rijsdijk & Sham, 2002). When the covariance is low, or not statistically significant, the variances in the phenotypes are not associated to each other and vary independently from one another, suggesting a lack of shared etiological associations (Weisstein, 2016).

As illustrated in Figure 2, which represents a genetic etiological association (r_A), the existence of an overlap (r_A^2) indicates that among the genetic factors that influence phenotype 1 (A_1), a portion of these (i.e., the overlapping section) *also* influence phenotype 2 (A_2). In other words, an etiological correlation indicates the degree to which the etiological factors that influence one phenotype also have that same effect on another phenotype.

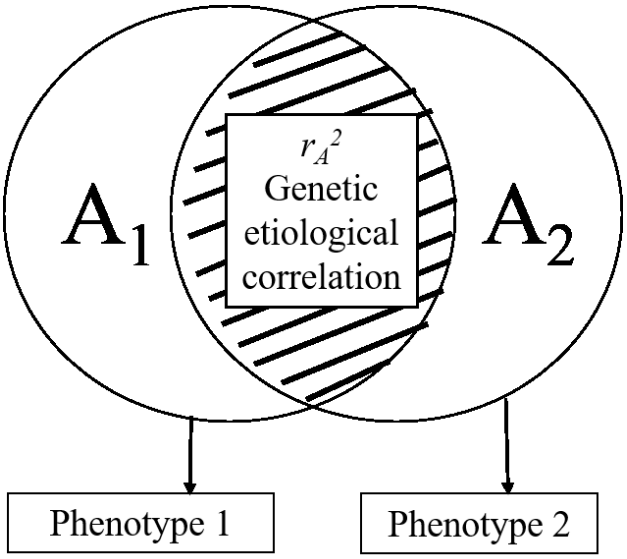

Figure 2. Genetic etiological correlation between phenotype 1 and phenotype 2 where A_1 indicates the genetic factors that influence phenotype 1, A_2 indicates the genetic factors that influence phenotype 2, and r_A^2 indicates the proportion of genetic factors that influence phenotype 1 as well as phenotype 2.

Bivariate analyses of variance, or Cholesky decompositions, as illustrated in Figure 3, calculate this etiological association by parsing genetic and environmental contributions into common latent factors (A_C, C_C, E_C), which affect the covariance between phenotypes, and unique latent factors (A_U, C_U, E_U), which are specific to the variance of the second phenotype (Brendgen et al., 2009). As seen in Figure 3, the a_{11}, c_{11} and e_{11} parameters represent the genetic,

shared environmental and non-shared environmental factor loadings of the first phenotype (i.e., CU traits) on the *common* latent factors; the a_{21}, c_{21} and e_{21} parameters represent the factor loadings of the second phenotype (i.e., conduct problems, hyperactivity or anxiety) on the *common* latent factors; and the a_{22}, c_{22} and e_{22} parameters represent the factor loadings of the second phenotype on the *unique* latent factors (Brendgen et al., 2009).

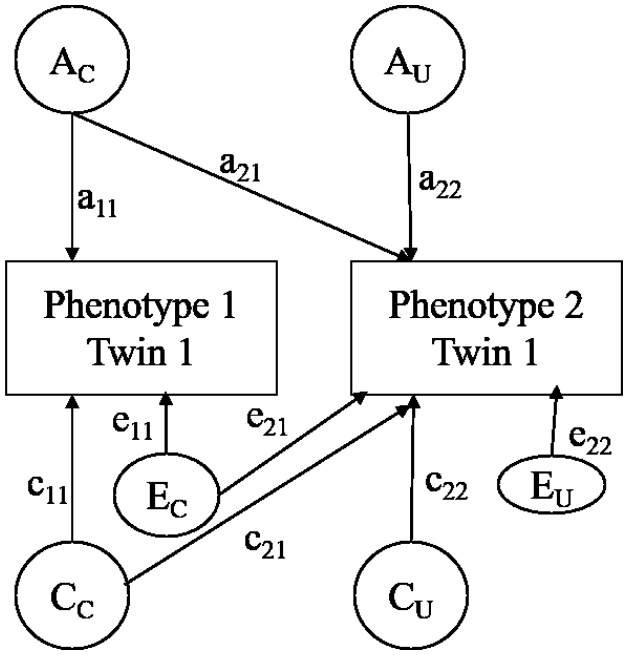

Figure 3. Overview of the bivariate Cholesky model representing common (A_C, C_C, E_C) and unique (A_U, C_U, E_U) latent factors used to evaluate the etiological associations between two phenotypes.

These parameters allow us to estimate the proportion of genetic, shared environmental and non-shared environmental contributions specific to each phenotype. The following formula was used to estimate the genetic contribution to the first phenotype (i.e., CU traits):

$$\%\mathrm{A}_1 = \frac{{a_{11}}^2}{{a_{11}}^2 + {c_{11}}^2 + {e_{11}}^2}$$

The genetic contribution to the second phenotype (i.e., conduct problems, hyperactivity or anxiety, depending on the pairing) was calculated using the following formula:

$$\%\mathrm{A}_2 = \frac{{a_{21}}^2 + {a_{22}}^2}{{a_{21}}^2 + {a_{22}}^2 + {c_{21}}^2 + {c_{22}}^2 + {e_{21}}^2 + {e_{22}}^2}$$

To calculate the proportion of shared and non-shared environmental contributions for each phenotype, we used the corresponding c and e parameters as numerators for each formula.

Next, we performed the Cholesky decompositions, which allowed us to estimate the degree of genetic, shared environmental and non-shared environmental associations between CU traits and the three other phenotypes. For instance, in our study, the relative contribution of A_C to the variance in conduct problems illustrated the genetic association between CU traits and conduct problems. This contribution is expressed as a correlation. The genetic correlation is illustrated by the following formula:

$$r_A = \frac{a_{11} \times a_{21}}{\sqrt{{a_{11}}^2({a_{21}}^2 + {a_{22}}^2)}}$$

We obtained the proportion of genetic variance of the second phenotype explained by genetic factors that *also* influenced the first phenotype (i.e., CU traits) by squaring this correlation. Equivalent shared environmental and non-shared environmental formulas were used in order to calculate the other correlations (r_C, r_E) and proportions of variance common to both phenotypes (r_C^2, r_E^2) for each pairing

It was then necessary to ensure that our models were consistent with the data provided. To do so, we estimated the fit of the full Cholesky model (i.e. ACE – ACE) for each of the three pairing. In some cases, the full ACE – ACE model does not fit the data as accurately as a nested model (e.g., AE – AE) might. Nested models are obtained by reducing certain factor loadings to 0 (Brendgen et al., 2012). Therefore, we next evaluated the fit of various nested models and compared them. We evaluated the fit of each of these bivariate models (both nested and full) using a maximum-likelihood function (Neale & Cardon, 1992). This function renders a goodness-of-fit statistic represented by a likelihood ratio chi-square (χ^2). A non-significant χ^2 value ($p > .05$) indicates that the model is consistent with the data and can be utilized. The model with the lowest Bayesian information criterion (BIC; Raftery, 1995; Schwarz, 1978), a model-fitting index based on the χ^2, was selected as best-fitting. We used full information maximum likelihood to include incomplete twin pairs in our model. All analyses were performed using Mplus (Version 7.31; Muthén & Muthén, 1998-2012).

CHAPTER 4: ARTICLE

Saunders, M.C., Lichtenstein, P. and Fontaine, N.M.G. (2017). The associations between callous-unemotional traits and symptoms of conduct problems, hyperactivity and anxiety: A study of adolescent twins. *To be submitted.*

M.C. Saunders was the main contributor to the writing and editing of the article as well as to the data analyses.

P. Lichtenstein reviewed the article and provided the database that was used for the analyses.

N.M.G. Fontaine contributed to the writing and editing of the article, as well as to the data analyses.

Abstract

Background. Callous-unemotional (CU) traits (e.g., lack of empathy, lack of guilt, shallow affect) are associated with severe and persistent conduct problems in youth. There is evidence showing a substantial genetic correlation between CU traits and conduct problems. The etiological associations between CU traits and other psychopathological symptoms, including symptoms of hyperactivity and anxiety, has been less explored. **Objectives.** To examine the etiological associations between CU traits and symptoms of conduct problems, hyperactivity and anxiety through the use of a twin design. **Method.** Participants were same-sex twin pairs (*n* = 426 twins; 42% female; 43% MZ; age = 15) drawn from the Child and Adolescents Twin Study in Sweden, a longitudinal study of twins born in Sweden. We used self-report measures of CU traits, conduct problems, hyperactivity and anxiety. Model-fitting analyses were conducted using structural equation modeling. **Results.** We found a strong positive genetic correlation between CU traits and conduct problems and a moderate genetic correlation between CU traits and hyperactivity. We also found a relatively modest, but significant negative genetic correlation between CU traits and anxiety. **Conclusion.** Findings on the etiological associations between CU traits and other psychopathological symptoms have potential implications for clinical practices and future research attempting to identify risk factors for CU traits.

Keywords: callous-unemotional traits, conduct problems, hyperactivity, anxiety, twin study

Callous-unemotional (CU) traits, which include characteristics such as lack of empathy, lack of guilt and shallow affect, are a well-documented temperamental risk factor for severe and persistent conduct problems in youth (Fontaine et al., 2011; Frick, Cornell, Bodin, et al., 2003). In addition, CU traits have been identified as a precursor to adult psychopathy (Lynam et al., 2007) and are considered the clinical hallmark of this syndrome (Cleckley, 1976; Hare, 2003). Evidence for a subset of youth with severe conduct problems distinguished by their high levels of CU traits led to the inclusion of CU traits as a specifier (labeled 'limited prosocial emotions') to conduct disorder in the *Diagnostic and Statistical Manual of Mental Disorders – 5th edition* (American Psychiatric Association, 2013).

Research on the development of persistent conduct problems, CU traits and adult psychopathy has also focused on the potential contribution of hyperactivity or attention deficit hyperactivity disorder (ADHD; e.g., Lynam, 1996) . There is evidence suggesting that conduct problems, CU traits and hyperactivity co-occur. Youth with conduct problems (Fontaine et al., 2008; Nagin & Tremblay, 2001) and youth with combined high levels of CU traits and conduct problems (Fontaine et al., 2011; Frick, Cornell, Barry, et al., 2003) are also likely to have high levels of hyperactivity. However, empirical findings suggest that the co-occurrence of conduct problems and hyperactivity does not designate a distinct group of youth at risk of developing psychopathy later on (Barry et al., 2000; Forsman et al., 2007).

While there is evidence suggesting that CU traits are associated with externalizing problems, such as conduct problems (Frick et al., 2014) and that externalizing problems are associated with internalizing problems, such as depression and anxiety (Russo & Beidel, 1994), the nature of the association between CU traits and internalizing problems is less clear. Based on

theory and clinical work, CU traits are expected to be negatively associated with anxiety (Cleckley, 1976). A number of empirical studies support this negative association (Frick et al., 1999; Pardini & Fite, 2010). However, other studies have reported no significant association between CU traits and anxiety (Loney et al., 2003; Neumann & Pardini, 2014). In addition, there are even findings suggesting a positive association between CU traits and anxiety (Essau et al., 2006; Fontaine et al., 2011). However, these findings may be explained by the fact that the unique and contrasting contributions of CU traits and conduct problems to anxiety were not explored: conduct problems, when controlling for CU traits, tend to be positively correlated with anxiety, whereas CU traits, when controlling for conduct problems, tend to be negatively correlated with anxiety (Frick & Dickens, 2006). Another explanation for these findings is that the heterogeneity in youth with CU traits and conduct problems was not considered. For instance, research has provided evidence for the distinction between primary and secondary CU traits in youth samples on the basis of anxiety, trauma and other psychological difficulties (Fanti et al., 2013; Kahn et al., 2013). Primary CU traits are expected to be associated with an inherent deficit expressed by an absence of conscience, lack of guilt and no feeling or regard for others, whereas secondary CU traits are expected to develop as a result of childhood maltreatment, inconsistent and harsh discipline, family conflicts, and rejection. Therefore, a negative association between CU traits and anxiety would be expected in the primary variant, but a positive association would be expected in the secondary variant.

Etiology of CU traits, conduct problems, hyperactivity and anxiety

Research based on twin samples has yielded important information concerning the etiology of CU traits, conduct problems, hyperactivity and anxiety. Findings showed moderate to

strong heritability of CU traits in youth, especially in boys (Fontaine et al., 2010), with estimates indicating that 40-78% of the variation in CU traits across the population was due to genetic contributions (Viding, Fontaine, & Larsson, 2013; Viding & McCrory, 2012). These studies have also suggested that non-shared environmental contributions were important to explain variation in CU traits. On the other hand, shared environmental contributions to CU traits were reported in only a small number of studies (Fontaine et al., 2010; Viding et al., 2007), although they may be especially important for a small subset of girls with stable and high levels of CU traits (Fontaine et al., 2010).

Moderate to strong genetic and non-shared environmental contributions have been found to explain the variation in conduct problems (Forsman et al., 2010; Viding et al., 2007) and anxiety (Blonigen et al., 2005; Mann et al., 2015) in youth samples. Shared environmental contributions were often modest or not significant. As for hyperactivity in youth samples, high heritability estimates and modest shared and non-shared environmental estimates were reported (Biederman, 2005).

A number of studies have examined the etiological association between CU traits and conduct problems. Genetic and non-shared environmental correlations were reported, but the strength of these correlations varied across studies (Bezdjian et al., 2011; Blonigen et al., 2005; H. Larsson et al., 2007; Viding et al., 2007). Importantly, moderate (Blonigen et al., 2005) to relatively strong (Viding et al., 2007) genetic correlations were found. Significant shared environmental correlations were not reported (Bezdjian et al., 2011; Blonigen et al., 2005; H. Larsson et al., 2007).

The etiological association between CU traits and other phenotypes, including hyperactivity and anxiety, has been less explored. To our knowledge, no published twin study has specifically examined the etiological overlap between CU traits and hyperactivity in youth. However, one twin study tested whether symptoms of ADHD were associated with different dimensions of psychopathic traits (including CU traits) in adolescence (Forsman et al., 2007). A modest phenotypic correlation was observed between CU traits and symptoms of ADHD, but the authors did not examine whether this association was explained by genetic, shared or non-shared environmental factors. The genetic association between CU traits (more specifically fearless dominance, which encompasses interpersonal-affective traits such as fearlessness and social potency) and internalizing problems (i.e., major depression, social phobia and simple phobia) was examined in a study of 17-year-old twins (Blonigen et al., 2005). This study revealed that fearless dominance exhibited a moderate negative genetic correlation with internalizing problems, indicating that the same genetic factors that contributed to fearless dominance traits also contributed to *reduced* levels of internalizing problems.

In sum, previous research showed that CU traits in youth are under the influence of moderate to strong heritability and that a modest to strong proportion of the factors that explain the genetic variance of conduct problems also explain the genetic variance of CU traits. The degree of etiological association between CU traits and other phenotypes, more specifically hyperactivity and anxiety, has been less explored. To address these limitations, the current study, employing a twin model-fitting approach, aimed to 1) replicate findings on the etiology of CU traits and their etiological association with conduct problems, and 2) extend research by examining further the etiological associations between CU traits and symptoms of hyperactivity

and anxiety. Findings from the current study will help to clarify the underlying etiological bases of CU traits and their associations with other psychopathological symptoms. In turn, this could inform clinical practices, notably by highlighting the sources of environmental influences (i.e., shared vs. non-shared environmental influences) that prevention and treatment strategies could target in order to help youth who are at risk or who have CU traits with or without co-occurring psychopathological symptoms.

Method

Participants

The participants were drawn from the Child and Adolescents Twin Study in Sweden (CATSS), an ongoing longitudinal twin study targeting all twins born in Sweden since July 1, 1992 (Anckarsäter et al., 2011). As of January 2010, the CATSS included approximately 17,220 twins, representing roughly 80% of all twins born in Sweden since July 1992 (Anckarsäter et al., 2011). The twins were screened at age 9 or 12 for different developmental problems, including ADHD, autism spectrum disorders, oppositional defiant disorder, conduct disorder, obsessive compulsive disorder and eating problems through the use of the Autism – Tics, ADHD and Other Comorbidities Inventory (A-TAC). The A-TAC is designed to evaluate all major clinical diagnostic criteria in child and adolescent psychiatry (Anckarsäter et al., 2011). Twins who scored above the associated cut-off corresponding to the various A-TAC modules were considered screen-positive (see Anckarsäter et al., 2011). Same-sex twin pairs for whom one or both twins screened positive as well as random control twin pairs were contacted to undergo a clinical evaluation at age 15 as part of the CATSS-15/Developmental Outcomes in a Genetic Twin Study in Sweden (DOGSS) data collection. Twins also completed self-report

questionnaires on a variety of physical and mental health subjects (see Anckarsäter et al., 2011, for more details about the procedures).

Briefly, a total of 451 same-sex twins, including 49 control participants who were screen-negative, born between the first of January 1993 and the 31st of December 1995 were included in the DOGSS and thus considered for the current study. Twins diagnosed with epilepsy, brain damage, chromosomal aberrations or intellectual disability (n = 25) were excluded from the analyses. The final sample included 426 twins aged 15 years (204 complete pairs, of which 24 were control participants, and 18 incomplete pairs, of which 1 was a control participant). Incomplete pairs indicate that the data at 15 years old were only available for one twin. In our sample, 38% of mothers and 21% of fathers had earned a university degree. The sample consisted of 43.4% monozygotic (MZ) twins (n = 185 twins; 79 female) and 56.6% dizygotic (DZ) twins (n = 241; 97 female). Zygosity was established through DNA analysis. For twins without DNA samples, an algorithm based on five questions on twin similarity was used. Twins were only assigned zygosity through the algorithm method if the test achieved a 95% probability of producing a correct categorization (Anckarsäter et al., 2011). The study and consent procedure were approved by the Karolinska Institute Ethical Review Board Dnr: 03-672 & 2010/1356/31/1.

Measures

CU traits

Self-reported CU traits were assessed using the CU dimension scale of the Youth Psychopathic traits Inventory (YPI; Andershed, Kerr, Statin & Levander, 2002). The CU dimension scale includes 15 items assessing callousness (e.g., "*When other people have*

problems, it is often their own fault, therefore, one should not help them"), unemotionality (e.g., "*I usually feel calm when other people are scared*,") and remorselessness *(e.g.,* "*I seldom regret things I do, even if other people feel that they are wrong*") (Andershed, Kerr, et al., 2002). Participants rated the degree to which the item applied to them using a 4-point scale with responses ranging from "*Does not apply at all*" to "*Applies very well*" (Andershed, Kerr, et al., 2002). The internal consistency (Cronbach's alpha) for this scale was .80. The YPI has demonstrated good construct validity in samples of adolescents (Neumann & Pardini, 2014; Poythress et al., 2006).

Conduct problems, hyperactivity and anxiety

Self-reported conduct problems (5 items, e.g., "*I fight a lot. I can make other people do what I want"*), hyperactivity (5 items, e.g., "*I am constantly fidgeting or squirming*") and anxiety (5 items, e.g., "*I worry a lot*") were assessed using the self-report version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, Meltzer & Bailey, 1998). Participants marked each item using a 3-point scale ("*Not true", "Somewhat true"* or *"Certainly true"*) (Goodman et al., 1998). Cronbach's alphas for conduct problems, hyperactivity and anxiety were .49, .75 and .72, respectively. The SDQ is an established screening instrument with well-confirmed validity and reliability (Goodman, 2001). Satisfactory internal consistency (Malmberg et al., 2003) and construct validity (Smedje et al., 1999) have been reported for the Swedish version of the SDQ. This version has also been shown to significantly distinguish between community and clinical samples (Malmberg et al., 2003).

Data analyses

We used a twin model-fitting approach in the current study. Twin studies rely on the comparison between intra-pair correlations in MZ twins (who are genetically identical) and in DZ twins (who on average share only half of their genes). From this comparison, sources of variability of a phenotype can be estimated in terms of latent genetic effects (A), latent shared environmental effects (C), and latent non-shared environmental effects (E), which also include measurement error (Neale & Cardon, 1992). When twins are reared together, it is assumed that MZ and DZ twins are equally similar in terms of their environment. When MZ twins are more similar to each other than DZ twins, it can be inferred that this difference is due to genetic effects. Any resemblance between MZ twins not due to genetic effects is attributed to common environmental effects. Differences between MZ twins are due to their non-shared environmental contributions (Rijsdijk & Sham, 2002).

Our aim was to evaluate the degree of etiological association between CU traits and other phenotypes (i.e., conduct problems, hyperactivity and anxiety). To this end, we applied a bivariate Cholesky twin model (see Figure 3) to each pair of phenotypes. Cholesky decompositions parse etiological contributions into common latent factors (A_C, C_C, E_C), which affect both phenotypes, and unique latent factors (A_U, C_U, E_U), which are specific to the second phenotype (Brendgen et al., 2009). As seen in Figure 3, the a_{11}, c_{11} and e_{11} parameters represent the genetic, shared environmental and non-shared environmental factor loadings of the first phenotype (i.e., CU traits) on the *common* latent factors; the a_{21}, c_{21} and e_{21} parameters represent the factor loadings of the second phenotype on the *common* latent factors; and the a_{22}, c_{22} and e_{22}

coefficients parameters the factor loadings of the second phenotype on the *unique* latent factors (Brendgen et al., 2009).

Using these parameters, we calculated the etiological contributions specific to each phenotype. The resulting genetic contribution to the etiology of the first phenotype (i.e. CU traits) is represented by the following formula:

$$\%\mathrm{A}_1 = \frac{{a_{11}}^2}{{a_{11}}^2 + {c_{11}}^2 + {e_{11}}^2}$$

The resulting genetic contribution to the etiology of the second phenotype (i.e. conduct problems, hyperactivity and anxiety) is represented by the following formula:

$$\%\mathrm{A}_2 = \frac{{a_{21}}^2 + {a_{22}}^2}{{a_{21}}^2 + {a_{22}}^2 + {c_{21}}^2 + {c_{22}}^2 + {e_{21}}^2 + {e_{22}}^2}$$

We used the corresponding shared environmental and non-shared environmental formulas to calculate the proportion of C and E contributions for each phenotype.

Next, the Cholesky decompositions allowed us to estimate the degree of etiological association between two phenotypes. The resulting genetic correlation is illustrated by the following formula:

$$r_A = \frac{a_{11} \times a_{21}}{\sqrt{{a_{11}}^2({a_{21}}^2 + {a_{22}}^2)}}$$

By squaring this correlation, we obtained the proportion of genetic variance of the second phenotype explained by genetic factors that *also* influenced the first phenotype (i.e. CU traits). We used the corresponding shared environmental and non-shared environmental formulas to

calculate the other correlations (r_C, r_E) and proportions of variance common to both phenotypes (r_C^2, r_E^2) for each of the three pairings.

In order to ensure that our bivariate models were consistent with the data, we estimated a full Cholesky model (i.e. ACE – ACE) for each of the pairings. Next, we evaluated the fit of a number of nested models (e.g., AE – AE), which are obtained by reducing certain factor loadings to 0 (Brendgen et al., 2012). We assessed the fit of each of these models using a maximum-likelihood function (Neale & Cardon, 1992). This function provides a goodness-of-fit statistic represented by a likelihood ratio chi-square (χ^2). A non-significant χ^2 value ($p > .05$) indicates that the model fits the data and can be used. The selection of best-fitting model was based on the model with the lowest Bayesian information criterion (BIC) (Raftery, 1995; Schwarz, 1978). We used full information maximum likelihood to include incomplete twin pairs in our model. All analyses were performed using Mplus (Version 7.31; Muthén & Muthén, 1998-2012).

Results

Descriptive statistics

Descriptive statistics for all 426 participants are displayed in Table 5. Square root transformations were applied to the conduct problems and anxiety scales to correct for skewness and kurtosis.

Table 5. Characteristics of the twins at age 15

	%	N	M	SD	Range	Skewness	Kurtosis
MZ	43.4	185					
Boys	58.7	250					
CU traits		407	13.29	6.53	0 – 35.00	0.48	-0.12
Conduct problems		414	1.17	0.63	0 – 3.00	-0.41	-0.08
Hyperactivity		413	3.54	2.39	0 – 10.00	0.38	-0.60
Anxiety		414	1.22	0.85	0 – 3.16	-0.17	-1.03

Note:
n = 426 twins; MZ = monozygotic twins; CU = callous-unemotional
Conduct problems and anxiety symptoms were square root transformed.

Phenotypic correlations

The phenotypic correlations between the phenotypes are displayed in Table 6. As expected, CU traits were positively correlated with conduct problems (r = .28, p < .001) and hyperactivity (r = .15, p < .01), and negatively correlated with anxiety (r = -.17, p < .01).

Table 6. Phenotypic correlations between CU traits, conduct problems, hyperactivity and anxiety

	1	2	3	4
1. CU traits	1			
2. Conduct problems	0.28***	1		
3. Hyperactivity	0.15**	0.51***	1	
4. Anxiety	-0.17**	0.19***	0.27***	1

Note:
n = 221 – 222 pairs; CU = callous-unemotional
** $p \leq .01$ *** $p \leq .001$

Intra-pair correlations

Intra-pair correlations for CU traits, conduct problems, hyperactivity and anxiety are shown in Table 7. Importantly, all the MZ correlations were higher than the DZ correlations, indicating evidence for genetic contributions to all four phenotypes.

Table 7. Intra-pair correlations for CU traits, conduct problems, hyperactivity and anxiety

	MZ	DZ
CU traits	0.64***	0.31**
Conduct problems	0.41***	0.29***
Hyperactivity	0.43***	0.07
Anxiety	0.53***	0.31***

Note:
n = 221 – 222 pairs; CU = callous-unemotional; MZ = monozygotic twins; DZ = dizygotic twins
** $p \leq .01$ *** $p \leq .001$

Bivariate analyses

We performed three sets of Cholesky bivariate decompositions: (1) CU traits – conduct problems, (2) CU traits – hyperactivity and (3) CU traits – anxiety. As displayed in Table 8, fit indices indicated that the AE – ACE model best fit the data for the etiological association between CU traits and conduct problems, whereas the AE – AE model best fit the data for the etiological association between CU traits and hyperactivity as well as between CU traits and anxiety.

Table 8. Model fitting results of bivariate analysis of CU traits and conduct problems, CU traits and hyperactivity, and CU traits and anxiety

	LL	df	χ^2	*p*	BIC
CU traits – conduct problems					
ACE x ACE	-1683.34	5	2.15	0.829	3426.12
ACE x AE	-1683.92	7	3.29	0.857	3416.46
AE x ACE	**-1683.37**	**7**	**2.19**	**0.949**	**3409.99**
AE x AE	-1683.93	8	3.32	0.913	3411.08
CU traits – hyperactivity					
ACE x ACE	-2243.69	5	5.24	0.388	4546.80
ACE x AE	-2243.78	7	5.43	0.608	4536.19
AE x ACE	-2243.81	7	5.49	0.600	4536.25
AE x AE	**-2243.81**	**8**	**5.49**	**0.704**	**4530.85**
CU traits – anxiety					
ACE x ACE	-1808.69	5	5.43	0.366	3676.81
ACE x AE	-1809.60	7	7.25	0.403	3667.82
AE x ACE	-1809.52	7	7.09	0.419	3667.66
AE x AE	**-1809.60**	**8**	**7.25**	**0.510**	**3662.42**

Note:
CU = callous-unemotional; LL = log likelihood; df = degrees of freedom; BIC = Bayesian information criterion
The best fitting models are in bold.

The bivariate parameter estimates associated with the best fitting models are displayed in Table 9. We used these to estimate the individual etiology of each phenotype. For instance, the variance in CU traits was mostly explained by genetic factors (63%), although there was evidence of a moderate non-shared environmental contribution (37%). The variance in conduct problems was explained by genetic (22%), shared environmental (19%), and non-shared environmental factors (59%). The variance in hyperactivity was explained by genetic (37%) and non-shared environmental (63%) factors. Lastly, the variance in anxiety was roughly divided into genetic (53%) and non-shared environmental (47%) contributions. We found no evidence of shared environmental contributions to the variance in CU traits, hyperactivity or anxiety.

Table 9. Bivariate parameters

	A	C	E	%A	%C	%E
CU traits – conduct problems (AE x ACE)						
CU traits[1]	5.16 (4.46; 5.81)	--	3.97 (3.27; 4.62)	62.9	--	37.1
Conduct problems				22.3	18.7	59.1
Common effects[2]	0.23 (0.14; 0.31)	--	-0.01 (-0.10; 0.09)			
Unique effects[3]	0.19 (0.00; 0.44)	0.27 (0.00; 0.37)	-0.49 (-0.55; -0.39)			
CU traits – hyperactivity (AE x AE)						
CU traits[1]	5.19 (4.48; 5.86)	--	3.94 (3.25; 4.59)			
Hyperactivity				36.7	--	63.3
Common effects[2]	0.52 (0.15; 0.90)	--	-0.07 (-0.43; 0.28)			
Unique effects[3]	1.34 (0.86; 1.67)	--	1.89 (1.64, 2.11)			
CU traits – anxiety (AE X AE)						
CU traits[1]	5.16 (4.45, 5.82)	--	3.96 (3.27, 4.60)			
Anxiety				52.9	--	47.1
Common effects[2]	-0.14 (-0.28, -0.01)	--	-0.03 (-0.15, 0.09)			
Unique effects[3]	0.60 (0.49, 0.68)	--	0.58 (0.49, 0.66)			

Note.
CU = Callous-unemotional; A = genetic effects; C = shared environment effects; E = non-shared environment effects.
1. associated parameters: : a_{11}, c_{11}, e_{11}; 2. associated parameters: a_{21}, c_{21}, e_{21} ; 3. associated parameters: a_{22}, c_{22}, e_{22}

We calculated the etiological correlations between each bivariate pairing (see Table 10). A strong genetic correlation was found between CU traits and conduct problems ($r_A = 0.77$ [0.37; 1.00]). This indicates that 59% (0.77^2) of the genetic variance of conduct problems was explained by factors that also explained the genetic variance of CU traits. A relatively moderate genetic correlation was found between CU traits and hyperactivity ($r_A = 0.36$ [0.11; 0.66]), indicating that 13% (0.36^2) of the genetic variance of hyperactivity was explained by genetic factors that also influenced CU traits. Lastly, a relatively modest, albeit significant negative additive genetic correlation was found between CU traits and anxiety ($r_A = -0.23$ [-0.44; -0.01]). This suggests that 8% (-0.23^2) of the genetic variance of anxiety was explained by factors that also explained the genetic variance of CU traits. Weak and non-significant non-shared environmental correlations were also found.

Table 10. Etiological correlations between CU traits and symptoms of conduct problems, hyperactivity and anxiety

	CU traits		
	r_A (95% CI)	r_C (95% CI)	r_E (95% CI)
Conduct problems	**0.77** (0.37 – 1.00)	--	-0.02 (-0.21 – 0.19)
Hyperactivity	**0.36** (0.11 – 0.66)	--	-0.04 (-0.23 – 0.15)
Anxiety	**-0.23** (-0.44 – -0.01)	--	-0.05 (-0.25 – 0.15)

Note:
CU = callous-unemotional; CI = confidence interval
A parameter is statistically significant if the CI does not include 0. A 95% CI indicates a 95% probability of the data being correctly classified.
Significant correlations are in bold.

Discussion

In this study, we examined the etiological associations between CU traits and symptoms of conduct problems, hyperactivity and anxiety through the use of a twin design. This allowed us 1) to replicate findings on the relatively high heritability of CU traits and the genetic correlation between CU traits and conduct problems, and 2) to investigate further the etiological associations between CU traits and symptoms of hyperactivity and anxiety. Findings from this study extend research in three main respects.

First, we found substantial genetic contributions to CU traits and a strong genetic correlation between CU traits and conduct problems. These findings are consistent with previous research examining the etiological association between CU traits and conduct problems in youth (Bezdjian et al., 2011; Viding et al., 2007). However, unlike previous studies (Bezdjian et al., 2011; Viding et al., 2007), we did not find a significant non-shared environmental correlation between CU traits and conduct problems, suggesting that in our sample, different environmental influences contribute to CU traits and conduct problems. Our findings strengthen the notion that CU traits and conduct problems are in part, but not entirely, genetically related. The substantial genetic correlation suggests that future molecular genetic research should focus on the identification of common genes that contribute to CU traits and conduct problems (Viding et al., 2007).

Second, to our knowledge, this is the first published study to examine the etiological association between CU traits and hyperactivity in youth. Although past research showed that the two phenotypes often co-occur (Fontaine et al., 2008; Fontaine et al., 2011; Frick, Cornell, Barry, et al., 2003; Nagin & Tremblay, 2001), our findings suggest that they share genetic

etiological factors, but only to some extent. Indeed, unlike CU traits and conduct problems, the genetic correlation between CU traits and hyperactivity was not strong. Future research is needed to further our understanding about the etiological associations between these phenotypes. Our findings, however, suggest that the genetic correlation between CU traits and conduct problems is greater that the genetic correlation between CU traits and hyperactivity. .

Third, we found a relatively modest, but significant negative genetic correlation between CU traits and anxiety, which is in line with the findings reported by Blonigen et al. (2005). In this previous study, a negative genetic correlation was reported between fearless dominance, which covered a wide range of interpersonal-affective traits associated with psychopathy, and internalizing problems, which included symptoms of phobia and depression. Because we focused on CU traits, instead of a wider range of interpersonal-affective traits, the current study extends previous findings by increasing the level of specificity in the examination of the etiological association between psychopathic traits and internalizing problems. The negative genetic correlation between CU traits and anxiety suggests that the genetic factors influencing the *increase* of one phenotype contribute to the *decrease* of the other. This could suggest that one behaviour may act as a protective factor against the other by preventing its development. Due to our sample size, we were unable to distinguish between primary and secondary CU traits. However, the negative phenotypic correlation between CU traits and anxiety suggests that the primary variant of CU traits may be more representative of our sample. With this in mind, our findings suggest that the genetic etiological processes that influence CU traits may also protect against anxiety, which lends support to studies reporting low levels of anxiety in the primary variant of CU traits (Fanti et al., 2013; Kahn et al., 2013).

There are a number of strengths to this study, including the use of a measure of CU traits over a broader measure of psychopathic traits, which increases the specificity of our findings. Moreover, to our knowledge, this was the first published study to explore the etiological association between CU traits and hyperactivity in youth. However, this study has a number of limitations. First, we were unable to conduct the analyses separately for boys and girls due to our sample size. Sex differences in the etiology of the behaviours at study have been previously reported. For instance, lower heritability and higher shared environmental contributions for CU traits (Fontaine et al., 2010; Viding et al., 2007) as well as lower shared and non-shared environmental correlations between CU traits and conduct problems have been found in girls (Viding et al., 2007). Second, the internal consistency of the measure of conduct problems was moderate ($\alpha = .49$). This could have produced more conservative estimates of the magnitude of the association between CU traits and conduct problems. However, it should be noted that low to moderate Cronbach's alphas of the measure of conduct problems as assessed by the self-report version of the SDQ were reported in several other studies (e.g., Muris, Meesters & van den Berg, 2003; Van Roy et al. 2008; van Widenfelt, Goedhart, Treffers & Goodman, 2003). Third, we assessed anxiety using the items from the emotional problems scale of the SDQ (Goodman, 2001). Although this scale has been found to be associated with other measures of anxiety (see e.g., Essau et al., 2012) replications of our findings using more comprehensive measures of anxiety disorders are needed. Fourth, because all the measures were based on the youths' reports, there is a possibility that our findings were partly influenced by shared method variance. Finally, our sample was aged 15 years old and combined participants who had screened positive for a developmental disorder and control participants from Sweden and is not representative of the

general population. Replications involving youth from various backgrounds are needed to increase the generalizability of our findings.

This study raises a number of clinical implications. First, it is important to note that genetic vulnerability does not mean immutability. Genetically-influenced behaviours can be buffered by preventive and treatment strategies, which could be considered as positive gene-environment interactions (Fontaine, McCrory, & Viding, in press). We found a genetic correlation between CU traits and conduct problems, but contrary to previous studies (Bezdjian et al., 2011; Viding et al., 2007), our findings suggest that different environmental factors contribute to each of these two phenotypes. We also found that different environmental factors contribute to CU traits and hyperactivity. Given the past and the current findings, future research is needed to identify measured environmental factors (e.g., parenting behaviours) that may be common or specific to CU traits and symptoms of conduct problems and hyperactivity, which in turn could be targeted in the context of intervention programs. Investigations focusing on child-specific environmental factors within twin designs may be particularly promising.

Second, our finding on the negative genetic correlation between CU traits and anxiety appears to be in line with the description of the primary variant of CU traits (Fanti et al., 2013; Kahn et al., 2013). This variant may confer a genetic resiliency to anxiety, but may also be associated with a lack of conscience, guilt and empathy, which should be considered while conducting a clinical assessment or implementing intervention strategies. For instance, approaches engaging empathy for a victim are unlikely to be successful with youth who are characterized by high levels of CU traits and low levels of anxiety (Viding, Simmonds, Petrides, & Frederickson, 2009). However, strategies aimed at buffering the development of serious and

persistent conduct problems in youth who are at risk because of their high levels of CU traits and low anxiety could have a positive impact on their developmental trajectory. Although CU traits have been found to be malleable (Fontaine et al., 2010; Frick et al., 2014; Hawes, Price, & Dadds, 2014), some degree of CU traits and low anxiety may be adaptive in certain contexts (e.g., when handling social rejection or criticism; Del Giudice, Hinnant, Ellis, & El-Sheikh, 2012). Future research is needed to understand better the constellations of traits and behaviours that are more likely to lead to adaptive behavioural patterns and positive life outcomes.

Third, as all four phenotypes examined in this study (i.e., CU traits, conduct problems, hyperactivity and anxiety) have been found to be heritable to some degree, a number of these youths may have parents with psychopathological vulnerabilities (Viding, Jones, Frick, Moffitt, & Plomin, 2008). It may be clinically beneficial to include the parents of the youths in the intervention process. For instance, it has been found that youth with high levels of CU traits respond to reward-based disciplinary strategies (Hawes & Dadds, 2005). Therefore, it could be important to help the parents of these youths in their ability to provide consistent reinforcement and implement other effective parenting strategies adapted to the strengths and vulnerabilities of their children (Viding et al., 2008).

In sum, we found a strong positive genetic correlation between CU traits and conduct problems, a relatively moderate genetic correlation between CU traits and hyperactivity, and a modest negative genetic correlation between CU traits and anxiety. Future research should focus on longitudinal studies, which may provide information on the stability of the etiological associations between CU traits and other psychopathological symptoms across ages. Finally, further research is also needed to examine potential sex differences as well as the etiological

association between different variants of CU traits (i.e., primary vs. secondary) and psychopathological symptoms.

CHAPTER 5: DISCUSSION AND CONCLUSION

Discussion

In this study, through the use of a twin design, we examined the etiological associations between CU traits and 1) conduct problems, 2) hyperactivity and 3) anxiety. As such, we were able to replicate findings on the etiological association between CU traits and conduct problems and extend knowledge on the etiological associations between CU traits and symptoms of hyperactivity and anxiety. The following section will first discuss these findings. This will be followed by the strengths and limitations of the study, as well as by the strengths and limitations of the twin design. Finally, clinical implications and suggestions for future research will be touched upon.

Etiology of CU traits, conduct problems, hyperactivity, and anxiety

The investigation of the etiological association between CU traits and various psychopathological symptoms also revealed the etiological contributions specific to each phenotype. Although not the primary purpose of our study, we will also touch upon these results, as they both replicated and challenged findings from previous studies.

First, in line with previous studies, we found a strong (A = 63%) genetic contribution to the variance in CU traits (Henry et al., 2016; Viding et al., 2005; Viding et al., 2007). Like a number of studies (e.g. H. Larsson et al., 2007; Taylor et al., 2003), we found no evidence of a shared environmental contribution, although this challenges reports from other studies (Fontaine et al., 2010; Henry et al., 2016). The lack of shared environmental influences found in our study is consistent with other studies using adolescent-aged samples (e.g. Blonigen et al., 2005) and studies using the YPI to measure CU traits (e.g. H. Larsson, Andershed, et al., 2006). Although

our sample contained a large number of participants who screened positive for developmental disorders, our findings replicate previous studies based on community samples (Blonigen et al., 2005; H. Larsson, Andershed, et al., 2006; Viding et al., 2005) and strengthen the notion that CU traits appear to be moderately to highly heritable.

Second, we found modest genetic (A = 22%) and shared environmental (C = 19%) contributions to the variance in conduct problems. Although a number of other studies reported stronger genetic contributions to conduct problems (e.g., Saudino et al., 2005; Viding et al., 2007), our results are consistent with findings from other Swedish twin samples. For instance, Forsman et al. (2010) reported a genetic contribution of 35% to the variance in conduct problems and H. Larsson et al. (2007) found genetic contributions of 19 to 31% to the variance in conduct problems in their sample of boys. The age of our participants may have influenced our results. As opposed to other studies that relied on samples of children, our sample was composed of adolescents. Some studies using younger samples (e.g. ages 7 to 12; Kerekes et al., 2014, Saudino et al., 2005, Viding et al., 2007) reported higher genetic contributions to conduct problems than a number of studies using older samples (e.g. ages 13 to 20; Forsman et al., 2010, H. Larsson et al., 2007). Also, research suggests that heritability estimates may vary depending on the age of onset of conduct problems in youth. Indeed, conduct problems in adolescents have been found to be more strongly influenced by environmental sources than those of younger children, which appear to be more strongly influenced by genetic sources (Frick & Dickens, 2006; Moffitt, 1993, 2003). Our sample of 15-year-olds, as opposed to samples of 7- to 12-year-olds, likely includes both youth whose conduct problems developed in childhood and those whose conduct problems developed in adolescence. As such, our findings on the etiology of

conduct problems may be confounded by the presence of two distinct groups with distinct etiological patterns.

Third, although we found a moderate genetic contribution (A = 37%) to the variance in hyperactivity, it was significantly weaker than expected (Biederman, 2005). This indicates that the hyperactivity symptoms of our participants were less influenced by genetic factors than the hyperactivity symptoms of participants in other samples. This may be due to nature of our measure. Whereas many studies used a parent-report measure (Kerekes et al., 2014; H. Larsson, Andershed, et al., 2006; J. O. Larsson et al., 2004; Saudino et al., 2005; Thapar et al., 2001), we relied on self-report to evaluate hyperactivity symptoms. It is possible that the participants in our clinical sample had difficulty evaluating their own hyperactivity symptoms, influencing the genetic estimates. On the other hand, we did not find evidence of a shared environmental contribution to the variance in hyperactivity, which is consistent with previous findings.

Fourth, we found a strong genetic contribution to the variance in anxiety (A = 53%). Although slightly higher, our findings are in line with previous research showing moderate-to-strong genetic influences in the etiology of anxiety (Blonigen et al., 2005; Brown et al., 2014; Eaves et al., 1997; Saudino et al., 2005). We found no evidence of shared environmental contributions. Our results strengthen the notion that anxiety is strongly influenced by both genetic and non-shared environmental factors.

Etiological associations

Findings from this study extend research in three main respects. First, we found a strong genetic correlation between CU traits and conduct problems. This is consistent with some studies

(Bezdjian et al., 2011; Viding et al., 2007) that also reported a strong genetic association between the two phenotypes. The genetic correlation we found was also considerably stronger than genetic correlations reported in other studies (Blonigen et al., 2005; H. Larsson et al., 2007). Unlike previous studies (Bezdjian et al., 2011; Viding et al., 2007), the non-shared environmental correlation we found was not significant. This suggests that in our sample, CU traits and conduct problems are influenced by distinct environmental factors. Our findings are important, as they suggest that common genes may be responsible for the association between CU traits and conduct problems. In short, CU traits and conduct problems may be in part, though not entirely, genetically related. Future molecular genetic studies may want to examine what genes contribute to the development of both CU traits and conduct problems (Viding et al., 2007).

Second, although previous research found strong behavioural associations between CU traits and hyperactivity (Fontaine et al., 2008; Fontaine et al., 2011; Nagin & Tremblay, 2001), we only found a moderate genetic correlation. However, the genetic correlation between CU traits and hyperactivity was weaker than the genetic correlation between CU traits and conduct problems. Furthermore, we found no evidence of shared or non-shared environmental correlations, which indicates that CU traits and hyperactivity do not share any environmental factors.

Third, we found a modest, but significant negative genetic correlation between CU traits and anxiety. This is consistent with findings reported by Blonigen et al. (2005), who found a moderate negative genetic correlation between “fearless dominance”, which included CU-like traits such as fearlessness and social potency, and internalizing problems, which included

symptoms of depression and phobia. Our study focused explicitly on CU traits and anxiety, instead of the wider range of interpersonal-affective traits and internalizing symptoms used in the previous study. For this reason, we extend past findings by increasing the level of specificity of the etiological association. The negative genetic correlation between CU traits and anxiety suggests that some of the genetic factors contributing to CU traits may also contribute to decreasing levels of anxiety and vice versa. Our relatively small sample made it impossible to distinguish between primary and secondary CU traits. However, the modest negative correlation between CU traits and anxiety suggests the primary variant may be over-represented in our sample. With this in mind, our findings indicate that some of genetic factors that influence CU traits may also confer a certain resiliency to anxiety, which is consistent with studies that reported low levels of anxiety in the primary variant of CU traits in youth (Fanti et al., 2013; Kahn et al., 2013).

Strengths

There are a number of important strengths to this study. First, the use of a measure of CU traits over a broader measure of psychopathy increased the specificity of our findings, as psychopathy has been shown to be constructed of different dimensions of behaviour and temperamental traits (Hare, 2003). Our use of the affective dimension, or CU traits, provides a more specific portrait of the clinical hallmark of psychopathy (Cleckley, 1976). Second, although others have examined the etiological association between hyperactivity and other dimensions of psychopathy than CU traits (Forsman et al., 2007), this study explored the etiological association between CU traits and hyperactivity more specifically. Third, although Blonigen et al. (2005) examined the relationship in a broader context (i.e,. the genetic correlation between psychopathic

traits and internalizing problems), our study examined the etiological association between CU traits and anxiety more specifically.

Limitations

However, this study has a number of limitations. First, we were not able to conduct sex difference analyses due to our small sample size. Some studies have reported important sex differences in the etiology of CU traits (Fontaine et al., 2010), conduct problems (Kerekes et al., 2014), hyperactivity (J. O. Larsson et al., 2004), and anxiety (Blonigen et al., 2005). Future studies would be needed to examine whether or not the current findings apply equally to both adolescent males and females.

Second, we found moderate internal consistency for the conduct problems scale ($\alpha = .49$). For this reason, more conservative estimates of the magnitude of the association between CU traits and conduct problems could have been produced. Importantly, however, several other studies have reported low to moderate Cronbach's alphas of the self-reported measure of conduct problems as assessed by the SDQ (e.g., Muris et al., 2003; Van Roy et al., 2008; van Widenfelt, et al., 2003).

Third, we used the emotional problems scale of the SDQ to assess anxiety. Although this scale includes several items directly tapping anxiety symptoms (e.g., *I worry a lot; I am nervous in new situations. I easily lose confidence*), one item relates to depressive symptoms (e.g., *I am often unhappy, down-hearted or tearful*) (Goodman et al., 1998). This implies that our results must be considered within a broad interpretation of anxiety symptoms. Furthermore, the emotional symptoms scale of the SDQ has been found to be associated with other measures of

anxiety, and particularly with measures of generalized anxiety, with correlations between the two ranging from .42 to .51 in samples from five different countries (Essau et al., 2012). Nonetheless, replications of our findings using more comprehensive measures of anxiety disorders are needed.

Fourth, because all the measures were based on the youth's reports, there is a possibility that our findings were partly influenced by shared method variance. Self-report measures have advantages and disadvantages. For instance, in the case of the YPI, self-report measures provide insight into subjective traits, such as lack of remorse or lack of empathy, which can be difficult to assess from an outside perspective, such as a parent or a teacher (Andershed, Kerr, et al., 2002). On the other hand, social desirability is a key factor to consider for self-report measures, as obviously negative items are likely to induce response biases in participants (Andershed, Kerr, et al., 2002; Poythress et al., 2006). Moreover, lying, deceit and manipulation are core symptoms of the psychopathic personality (Hare, 2003), and it has been found that adolescents with psychopathic traits may show a lack of insight into their own behaviour (Andershed, Kerr, et al., 2002). It is reasonable to assume that some of our participants, in particular those with higher levels of CU traits, may not have been fully equipped to self-report their behavioural and temperamental difficulties. However, as mentioned previously, the YPI was specifically designed to address these limitations, for instance by framing psychopathic traits as abilities in order to reduce distortion due to social desirability (Andershed, Kerr, et al., 2002). The YPI also discourages participants from lying by presenting items in a way that is favourable to people with psychopathic traits but not to others (e.g. "*I don't let my feelings affect me as much as other people's feelings seem to affect them*"). By tapping items indirectly, instead of directly (e.g., "*My emotions are less strong than other peoples"* as a comparison for the item mentioned above), the

YPI minimises problems related to lack of insight into how the respondents compare to others (Andershed, Kerr, et al., 2002). As such, our use of the YPI as a self-report measure of CU traits overcomes many of the problems associated with other instruments. In the case of the SDQ, it may have been difficult for participants to gauge accurately some of their behavioural problems. However, the self-report version of the SDQ has demonstrated good inter-rater correlations with teacher- and parent-report versions, (Goodman et al., 1998) which suggests that participants were adequately able to rate their own behaviours.

Fifth, our sample was composed of a number of participants who screened positive for a developmental disorder and control 15-year-old participants born in Sweden. We ran the analyses both with and without the control participants and the pattern of findings remained the same. However, our sample is not representative of the general population. In order to increase the generalizability of our findings, replications with youth from various cultural and socio-demographic backgrounds are necessary.

Strengths and limitations of the twin design

A twin design is an effective way of estimating etiological contributions. Other quantitative genetics methods have important limitations, such as the inability of family studies to distinguish between genetic and shared familial factors, or the inability of adoption studies to account for prenatal environmental effects or selective placement bias (Rijsdijk & Sham, 2002). Although twin studies overcome these issues, there are other limitations related to the assumptions inherent to the twin design.

First, the twin design relies on the assumption that twins are representative of the population and can be compared to children of single birth. Although most studies have found that twins can be compared to singletons on most facets, twins have lower average birth weights than singletons and are born, on average, three weeks prematurely (Rijsdijk & Sham, 2002). Low birth weight and prematurity have been associated with both internalizing and externalizing problems, in particular ADHD (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Gray, Indurkhya, & McCormick, 2004). Furthermore, there is some evidence that twins are at a higher risk of congenital anomalies and birth complications (Brendgen et al., 2012). In our study, twins with epilepsy, brain damage, chromosomal aberrations or intellectual disability were excluded from our study, which decreases the scope of this limitation.

Second, it is assumed that MZ twins are genetically identical. However, some studies have found variations in the DNA sequences of identical twins, suggesting that genetic effects may be slightly underestimated in classical twin studies such as ours (Brendgen et al., 2012).

The third assumption used in twin studies is the equal environments assumption, which states that MZ and DZ twins share their environment to the same extent. However, there is some evidence that MZ twins are treated more similarly than DZ twins, for instance by their parents requesting they be placed in the same classroom (Plomin, DeFries, McClearn, & McGuffin, 2001). This differential treatment could potentially lead to increased correlations between MZ twins over DZ twins, therefore creating an overestimation of the genetic etiological contribution and an underestimation of the shared environmental contribution (Rijsdijk & Sham, 2002). However, there is little evidence that differential treatment has any significant effect on intra-twin correlations. For one, little to no mislabeling effect has been found. In other words, studies

have not reported increased similarity in DZ twins mislabeled as MZ twins, nor any decreased similarity in MZ twins mislabeled as DZ twins (Rijsdijk & Sham, 2002). For another, intra-twin correlations in studies where MZ twins were reared apart were almost the same as those for MZ twins raised together (Rijsdijk & Sham, 2002). This suggests that the phenotypic similarity between MZ twins exists regardless of whether they were treated more or less the same way as DZ twins.

The fourth assumption twin studies rely on is that no assortative mating occurs, i.e., that people do not choose their mate based on genotypic similarity. Yet, there is evidence that spouses resemble each other on a number of characteristics, implying that mating may not be absolutely random (Brendgen et al., 2012). If assortative mating occurs, parents will resemble each other genetically, leading to an increased genetic similarity in DZ twins, who would therefore share more than 50% of their genes. This would decrease the difference between MZ and DZ intra-pair correlations and potentially lead to an overestimation of the shared environmental influence (Brendgen et al., 2012; Rijsdijk & Sham, 2002). However, the only way to detect this effect is to analyse the similarity between spouses over time or test the resemblance between spouses of biologically related people (Rijsdijk & Sham, 2002), which involves costs, resources and time that the majority of studies cannot afford. Thus, it must be considered that the reported shared environmental contributions may be slightly inflated in any twin study. Nonetheless, because we found small to no shared environmental contributions for any of the phenotypes, and no evidence of shared environmental correlations for any of the pairings (e.g., CU traits and conduct problems), this limitation does not critically affect our study.

The final, and possibly the most critical limitation of the twin model, is that genetic and environmental influences are assumed to be independent of each other (Brendgen et al., 2012). However, research has found that this may not be the case, and this non-independence can be found in the form of both gene-environment correlations and gene-environment interactions. Undetected gene-environmental correlations or gene-environment interactions may result in biased results concerning etiological contributions (Brendgen et al., 2012). Future research would be needed in order to evaluate the role of gene-environment interplay in the etiology and etiological associations of the phenotypes in this study.

Implications

A number of implications arise from this study. First, although we found important genetic contributions to each phenotype, this by no means implies that the behaviours are immutable. Preventative and treatment strategies can affect the development of genetically-influenced behaviours, which would represent positive gene-environment interactions (Fontaine et al., in press). In short, genetics do not imply destiny. Although we found a strong genetic correlation between CU traits and conduct problems, we found no evidence of any environmental etiological correlation between the two, which challenges previous studies (Bezdjian et al., 2011; Viding et al., 2007). Instead, our findings suggest that the etiology of these two phenotypes is influenced by distinct environmental factors. According to our results, the same can be said for the etiological association between CU traits and hyperactivity. Given past and current findings, future research could focus on the identification of measured environmental factors (e.g., parenting behaviours) that may be specific to CU traits, conduct problems or hyperactivity. In turn, these factors could be targeted in the context of treatment and prevention programs. For

instance, research has found that punitive discipline had little effect on the behaviour of youth with CU traits and that behavioural modification may instead stem from rewarding good behaviour (Hawes & Dadds, 2005; Viding et al., 2009). As such, an intervention program for youth with CU traits may focus on increasing parental warmth and highlighting the importance of reward-based discipline.

Second, the negative genetic correlation that we found between CU traits and anxiety is consistent with the description of the primary variant of CU traits, which was shown to be associated with low levels of anxiety in youth samples (Fanti et al., 2013; Kahn et al., 2013). This negative genetic correlation implies that youth with primary CU traits may show a genetic resiliency to anxiety (and vice versa). In terms of clinical implications, these findings could suggest that due to the limited empathy associated with primary CU traits, approaches that rely heavily on engaging empathy for others may not be optimal for youth with these traits (Viding et al., 2009). For another, interventions that focus on making youth aware of the negative consequences of their behaviour may not be beneficial to youth with primary CU traits, as they do not appear to be troubled when they misbehave (Andershed, Gustafson, et al., 2002; Frick et al., 1999). On the other hand, intervention programs could improve the developmental outcomes of youth characterized by high levels of CU traits and low levels of anxiety by focusing on the prevention and treatment of serious and persistent conduct problems. Furthermore, research has found that CU traits in youth can be malleable (Fontaine et al., 2010; Frick et al., 2014; Hawes et al., 2014). In other words, high levels of CU traits can decrease over time in some youth. Still, some degree of CU traits and low levels of anxiety could be beneficial in some situations, for instance when handling social rejection or criticism. Indeed, these characteristics could be a sign

of adaptation, inhibiting stress responses otherwise engendered by these contexts (Del Giudice et al., 2012). There is also evidence suggesting that some individuals with CU traits and low anxiety may handle high-risk situations well and may be inclined to enter risky occupations such as police work or firefighting (Lilienfeld, Latzman, Watts, Smith, & Dutton, 2014). Future research that focuses on identifying the constellations of traits and behaviours that are more likely to stimulate positive outcomes through an adaptive behavioural pattern could lead to a better understanding of this adaptive quality.

Third, it is important to note that all four phenotypes examined in this study (i.e., CU traits, conduct problems, hyperactivity, and anxiety) were found to be heritable to some degree. This finding suggests that a number of these youths may have parents who are themselves struggling with psychopathological vulnerabilities (Viding et al., 2008). For this reason, including the parents of the youths in the intervention process may be clinically beneficial for improved outcomes. For instance, strategies that help the parents of these youths in their ability to provide consistent, reward-based reinforcement may prove to be successful, as it was found that youth with CU traits respond better to this type of discipline (Hawes & Dadds, 2005). It could also be important to implement other effective parenting strategies that are better adapted to the strengths and vulnerabilities of the parents as well as to those of their children (Viding et al., 2008).

Future studies

Should future research make use of a longitudinal twin design, this could provide information concerning the stability of the etiological associations between CU traits and conduct problems, hyperactivity and anxiety. CU traits have been found to show varying levels

of stability: whereas the levels of CU traits of some youth appear to be stable (either low or high), a sizeable portion of youth can show decreasing or increasing levels of CU traits over time (Fontaine et al., 2010). Future studies should therefore also focus on developmental trajectory analyses in combination with etiological analyses. For instance, non-shared environmental factors appear to be more important to the etiology of increasing and decreasing levels of CU traits in boys as opposed to the etiology of stable low and high levels (Fontaine et al., 2010). It is thus possible that youth with increasing or decreasing levels of CU traits over time may show different etiological associations with other psychopathological symptoms than youth with stable levels.

Furthermore, the examination of potential sex differences in the etiology of CU traits, conduct problems, hyperactivity and anxiety and in their etiological associations seems critical, as a number of studies have reported important sex differences (e.g., Fontaine et al., 2010; Kerekes et al., 2014). To do so, future research will require sample sizes larger than the one we used. Larger samples could also lead to the examination of the etiological associations between different variants of CU traits (i.e., primary vs. secondary) and psychopathological symptoms. Replications involving samples of different ages and origins are also needed.

Finally, future studies may consider the impact of gene-environment interplay on the etiological associations between these phenotypes. Gene-environment correlations consider the fact that exposure to environments is not random and that genetic factors may influence the decisions of individuals concerning the environments they are exposed to. Gene-environment interactions refer to the differential response between genotypes to the same environment: some individuals will be more sensitive than others to the same environmental factor (Rijsdijk &

Sham, 2002). For instance, a child's genetic predisposition towards callousness may be strengthened by lower levels of parental warmth (gene-environment interaction), which could lead to higher levels of CU traits and conduct problems. By considering the potential effects of gene-environment interplay, future research could present a more detailed portrait of the etiology of these phenotypes and the etiological associations between these phenotypes.

Conclusion

This study aimed to examine the etiological associations between CU traits and 1) conduct problems, 2) hyperactivity and 3) anxiety through the use of a twin design. We found a relatively strong positive genetic correlation between CU traits and conduct problems, a moderate positive correlation between CU traits and hyperactivity, and a modest negative genetic correlation between CU traits and anxiety.

Our findings are important, as they replicated previous results concerning the etiological association between CU traits and conduct problems, and extend knowledge on the etiological association between CU traits and hyperactivity and between CU traits and anxiety.

Other studies have shown that CU traits and conduct problems often co-occur (Frick, 2009) and our results suggest this may be due, at least in part, to their genetic etiological association. Moreover, youth with combined CU traits and conduct problems represent a particularly high-risk group of youth in terms of antisocial outcomes (Frick, Cornell, Barry, et al., 2003). Although the genetic correlation may not be as great as for CU traits and conduct problems, our findings suggest that CU traits and hyperactivity share some genetic factors. Lastly, our results indicate that the negative etiological association between CU traits and anxiety

may confer a form of protective factor towards anxiety in youth with high levels of CU traits (and vice versa).

Our study has contributed to the development of the understanding of CU traits and their etiological associations with conduct problems, hyperactivity and anxiety. Future research could work on identifying specific environmental factors that contribute to the development of these traits, which in turn could better inform clinical practices. Molecular genetic research could focus on the identification of genes that are common to the etiology of both CU traits and conduct problems (Viding et al., 2007). Furthermore, further research should focus on potential sex differences and the etiological association between different variants of CU traits (i.e., primary vs. secondary) and psychopathological symptoms. Finally, longitudinal studies are needed to examine the stability of the etiological associations between CU traits and other psychopathological symptoms over time.

REFERENCES

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders*. Washington, DC: American Psychiatric Association.

Anckarsäter, H., Lundström, S., Kollberg, L., Kerekes, N., Palm, C., Carlström, E., . . . Lichtenstein, P. (2011). The child and adolescent twin study in Sweden (CATSS). *Twin Research and Human Genetics, 14*(06), 495-508. doi:10.1375/twin.14.6.495

Andershed, H., Gustafson, S. B., Kerr, M., & Stattin, H. (2002). The usefulness of self-reported psychopathy-like traits in the study of antisocial behaviour among non-referred adolescents. *European Journal of Personality, 16*(5), 383-402. doi:10.1002/per.455

Andershed, H., Kerr, M., Stattin, H., & Levander, S. (2002). Psychopathic traits in non-referred youths: A new assessment tool. In E. Blaauw & L. Sheridan (Eds.), *Psychopaths: Current International Perspectives* (pp. 131-158). The Hague: Elsevier.

Barry, C. T., Frick, P. J., DeShazo, T. M., McCoy, M., Ellis, M., & Loney, B. R. (2000). The importance of callous-unemotional traits for extending the concept of psychopathy to children. *Journal of Abnormal Psychology, 109*(2), 335-340. doi:10.1037/0021-843x.109.2.335

Bezdjian, S., Tuvblad, C., Raine, A., & Baker, L. A. (2011). The genetic and environmental covariation among psychopathic personality traits, and reactive and proactive aggression in childhood. *Child Development, 82*(4), 1267-1281. doi:10.1111/j.1467-8624.2011.01598.x

Bhutta, A. T., Cleves, M. A., Casey, P. H., Cradock, M. M., & Anand, K. J. S. (2002). Cognitive and behavioral outcomes of school-aged children who were born preterm: A Meta-analysis. *Journal of the American Medical Association, 288*(6), 728-737.

Biederman, J. (2005). Attention-deficit/hyperactivity disorder: a selective overview. *Biological Psychiatry, 57*(11), 1215-1220. doi:10.1016/j.biopsych.2004.10.020

Blonigen, D. M., Hicks, B. M., Krueger, R. F., Patrick, C. J., & Iacono, W. G. (2005). Psychopathic personality traits: heritability and genetic overlap with internalizing and externalizing psychopathology. *Psychological Medicine, 35*(5), 637-648. doi:10.1017/s0033291704004180

Brendgen, M., Vitaro, F., Boivin, M., Girard, A., Bukowski, W. M., Dionne, G., . . . Perusse, D. (2009). Gene-environment interplay between peer rejection and depressive behavior in children. *Journal of Child Psychology and Psychiatry, 50*(8), 1009-1017. doi:10.1111/j.1469-7610.2009.02052.x

Brendgen, M., Vitaro, F., & Girard, A. (2012). Evaluating gene-environment interplay. In B. Laursen, T. D. Little, & N. A. Card (Eds.), *Handbook of developement research methods* (pp. 687-705). New York, NY: Guilford.

Brown, H. M., Waszczuk, M. A., Zavos, H. M., Trzaskowski, M., Gregory, A. M., & Eley, T. C. (2014). Cognitive content specificity in anxiety and depressive disorder symptoms: a twin study of cross-sectional associations with anxiety sensitivity dimensions across development. *Psychological Medicine, 44*(16), 3469-3480. doi:10.1017/S0033291714000828

Christian, R. E., Frick, P. J., Hill, N. L., Tyler, L., & Frazer, D. R. (1997). Psychopathy and conduct problems in children: II. Implications for subtyping children with conduct problems. *Journal of the American Academy of Child & Adolescent Psychiatry, 36*(2), 233-241.

Cleckley, H. (1941). *The mask of sanity: An attempt to reinterpret the so-called psychopathic personality* (5th ed.). St Louis, MO: Mosby.

Cleckley, H. (1976). *The mask of sanity* (5th ed.). St Louis, MO: Mosby.

Dadds, M. R., Fraser, J., Frost, A., & Hawes, D. J. (2005). Disentangling the underlying dimensions of psychopathy and conduct problems in childhood: a community study. *Journal of Consulting and Clinical Psychology, 73*(3), 400-410. doi:10.1037/0022-006X.73.3.400

Del Giudice, M., Hinnant, J. B., Ellis, B. J., & El-Sheikh, M. (2012). Adaptive patterns of stress responsivity: a preliminary investigation. *Developmental Psychology, 48*(3), 775.

Eaves, L., Silberg, J., Meyer, J., Maes, H., Simonoff, E., Pickles, A., . . . Hewitt, J. (1997). Genetics and developmental psychopathology: 2. The main effects of genes and environment on behavioral problems in the Virginia twin study of adolescent behavioral development. *Journal of Child Psychology and Psychiatry, 38*(8), 965-980.

Essau, C. A., Olaya, B., Anastassiou-Hadjicharalambous, X., Pauli, G., Gilvarry, C., Bray, D., . . . Ollendick, T. H. (2012). Psychometric properties of the Strength and Difficulties Questionnaire from five European countries. *International Journal of Methods in Psychiatric Research, 21*(3), 232-245.

Essau, C. A., Sasagawa, S., & Frick, P. J. (2006). Callous-unemotional traits in a community sample of adolescents. *Assessment, 13*(4), 454-469. doi:10.1177/1073191106287354

Fanti, K. A., Demetriou, C. A., & Kimonis, E. R. (2013). Variants of callous-unemotional conduct problems in a community sample of adolescents. *Journal of Youth and Adolescence, 42*(7), 964-979. doi:10.1007/s10964-013-9958-9

Fontaine, N. M., Barker, E. D., Salekin, R. T., & Viding, E. (2008). Dimensions of psychopathy and their relationships to cognitive functioning in children. *Journal of Clinical Child & Adolescent Psychology, 37*(3), 690-696. doi:10.1080/15374410802148111

Fontaine, N. M., McCrory, E. J., Boivin, M., Moffitt, T. E., & Viding, E. (2011). Predictors and outcomes of joint trajectories of callous-unemotional traits and conduct problems in childhood. *Journal of Abnormal Psychology, 120*(3), 730-742. doi:10.1037/a0022620

Fontaine, N. M., McCrory, E. J., & Viding, E. (in press). Genetic contributions to the development of psychopathic traits and antisocial behavior in youths. In A. Beech, A. J. Carter, R. Mann, & P. Rothstein (Eds.), *The Wiley Handbook of Forensic Neuroscience*. Oxford, UK: Wiley Blackwell.

Fontaine, N. M., Rijsdijk, F., McCrory, E. J., & Viding, E. (2010). Etiology of different development trajectories of callous-unemotional traits. *Journal of the American Academy of Child & Adolescent Psychiatry, 49*(7), 656-664. doi:10.1016/j.jaac.2010.03.014

Forsman, M., Larsson, H., Andershed, H., & Lichtenstein, P. (2007). The association between persistent disruptive childhood behaviour and the psychopathic personality constellation in adolescence: A twin study. *British Journal of Developmental Psychology, 25*(3), 383-398. doi:10.1348/026151006x158799

Forsman, M., Lichtenstein, P., Andershed, H., & Larsson, H. (2010). A longitudinal twin study of the direction of effects between psychopathic personality and antisocial behaviour. *Journal of Child Psychology and Psychiatry, 51*(1), 39-47. doi:10.1111/j.1469-7610.2009.02141.x

Frick, P. J. (2009). Extending the construct of psychopathy to youth: Implications for understanding, diagnosing and treating antisocial children and adolescents. *The Canadian Journal of Psychiatry, 54*(12), 23-32.

Frick, P. J., Barry, C. T., & Bodin, S. D. (2000). Applying the concept of psychopathy to children: Implications for the assessment of antisocial youth. In C. Gacono (Ed.), *The clinical and forensic assessment of psychopathy: A practitioner's guide* (pp. 3-24). London: Routledge.

Frick, P. J., Cornell, A. H., Barry, C. T., Bodin, S. D., & Dane, H. E. (2003). Callous-unemotional traits and conduct problems in the prediction of conduct problem severity, aggression, and self-report of delinquency. *Journal of Abnormal Child Psychology, 31*(4), 457-470. doi:10.1023/a:1023899703866

Frick, P. J., Cornell, A. H., Bodin, S. D., Dane, H. E., Barry, C. T., & Loney, B. R. (2003). Callous-unemotional traits and developmental pathways to severe conduct problems. *Developmental Psychology, 39*(2), 246-260. doi:10.1037/0012-1649.39.2.246

Frick, P. J., & Dickens, C. (2006). Current perspectives on conduct disorder. *Current Psychiatry Reports, 8*(1), 59-72.

Frick, P. J., Lilienfeld, S. O., Ellis, M. L., Loney, B. R., & Silverthorn, P. (1999). The association between anxiety and psychopathy dimensions in children. *Journal of Abnormal Child Psychology, 27*(5), 383-392.

Frick, P. J., Ray, J. V., Thornton, L. C., & Kahn, R. E. (2014). Can callous-unemotional traits enhance the understanding, diagnosis, and treatment of serious conduct problems in children and adolescents? A comprehensive review. *Psychological Bulletin, 140*(1), 1.

Goodman, R. (1997). The Strengths and Difficulties questionnaire: A research note. *Journal of Child Psychology and Psychiatry, 38*(5), 581-586.

Goodman, R. (2001). Psychometric properties of the strengths and difficulties questionnaire. *Journal of the American Academy of Child & Adolescent Psychiatry, 40*(11), 1337-1345.

Goodman, R., Meltzer, H., & Bailey, V. (1998). The strengths and difficulties questionnaire: A pilot study on the validity of the self-report version. *European Child and Adolescent Psychiatry, 7*(3), 125-130.

Gray, R. F., Indurkhya, A., & McCormick, M. C. (2004). Prevalence, stability, and predictors of clinically significant behavior problems in low birth weight children at 3, 5, and 8 years of age. *Pediatrics, 114*(3), 736-743. doi:10.1542/peds.2003-1150-L

Hare, R. D. (2003). *Manual for the Revised Psychopathy Checklist* (2nd ed.). Toronto, ON: Multi-Health Systems.

Hawes, D. J., & Dadds, M. R. (2005). The treatment of conduct problems in children with callous-unemotional traits. *Journal of Consulting and Clinical Psychology, 73*(4), 737-741. doi:10.1037/0022-006X.73.4.737

Hawes, D. J., Price, M. J., & Dadds, M. R. (2014). Callous-unemotional traits and the treatment of conduct problems in childhood and adolescence: A comprehensive review. *Clinical Child and Family Psychology Review, 17*(3), 248-267.

Henry, J., Pingault, J. B., Boivin, M., Rijsdijk, F., & Viding, E. (2016). Genetic and environmental aetiology of the dimensions of callous-unemotional traits. *Psychological Medicine, 46*(2), 405-414. doi:10.1017/S0033291715001919

Kahn, R. E., Frick, P. J., Youngstrom, E. A., Kogos Youngstrom, J., Feeny, N. C., & Findling, R. L. (2013). Distinguishing primary and secondary variants of callous-unemotional traits

among adolescents in a clinic-referred sample. *Psychological Assessment, 25*(3), 966-978. doi:10.1037/a0032880

Karpman, B. (1948). Conscience in the psychopath: another version. *American Journal of Orthopsychiatry, 18*(3), 455.

Kerekes, N., Lundstrom, S., Chang, Z., Tajnia, A., Jern, P., Lichtenstein, P., . . . Anckarsater, H. (2014). Oppositional defiant- and conduct disorder-like problems: neurodevelopmental predictors and genetic background in boys and girls, in a nationwide twin study. *PeerJ, 2*, e359. doi:10.7717/peerj.359

Larsson, H., Andershed, H., & Lichtenstein, P. (2006). A genetic factor explains most of the variation in the psychopathic personality. *Journal of Abnormal Psychology, 115*(2), 221-230. doi:10.1037/0021-843X.115.2.221

Larsson, H., Lichtenstein, P., & Larsson, J. O. (2006). Genetic contributions to the development of ADHD subtypes from childhood to adolescence. *Journal of the American Academy of Child & Adolescent Psychiatry, 45*(8), 973-981. doi:10.1097/01.chi.0000222787.57100.d8

Larsson, H., Tuvblad, C., Rijsdijk, F. V., Andershed, H., Grann, M., & Lichtenstein, P. (2007). A common genetic factor explains the association between psychopathic personality and antisocial behavior. *Psychological Medicine, 37*(1), 15-26. doi:10.1017/S003329170600907X

Larsson, J. O., Larsson, H., & Lichtenstein, P. (2004). Genetic and environmental contributions to stability and change of ADHD symptoms between 8 and 13 years of age: a longitudinal twin study. *Journal of the American Academy of Child & Adolescent Psychiatry, 43*(10), 1267-1275. doi:10.1097/01.chi.0000135622.05219.bf

Lilienfeld, S. O., Latzman, R. D., Watts, A. L., Smith, S. F., & Dutton, K. (2014). Correlates of psychopathic personality traits in everyday life: results from a large community survey. *Frontiers in Psychology, 5*, 740. doi:10.3389/fpsyg.2014.00740

Loney, B. R., Frick, P. J., Clements, C. B., Ellis, M. L., & Kerlin, K. (2003). Callous-unemotional traits, impulsivity, and emotional processing in adolescents with antisocial behavior problems. *Journal of Clinical Child & Adolescent Psychology, 32*(1), 66-80. doi:10.1207/S15374424JCCP3201_07

Lynam, D. R. (1996). Early identification of chronic offenders: Who is the fledgling psychopath? *Psychological Bulletin, 120*(2), 209-234.

Lynam, D. R., Caspi, A., Moffitt, T. E., Loeber, R., & Stouthamer-Loeber, M. (2007). Longitudinal evidence that psychopathy scores in early adolescence predict adult psychopathy. *Journal of Abnormal Psychology, 116*(1), 155-165. doi:10.1037/0021-843X.116.1.155

Malmberg, M., Rydell, A. M., & Smedje, H. (2003). Validity of the Swedish version of the Strengths and Difficulties Questionnaire (SDQ-Swe). *Nord J Psychiatry, 57*(5), 357-363. doi:10.1080/08039480310002697

Mann, F. D., Briley, D. A., Tucker-Drob, E. M., & Harden, K. P. (2015). A behavioral genetic analysis of callous-unemotional traits and Big Five personality in adolescence. *Journal of Abnormal Psychology, 124*(4), 982-993. doi:10.1037/abn0000099

Moffitt, T. E. (1993). Adolescence-limited and life-course persistent antisocial behaviour: A developmental taxonomy. *Psychological Review, 100*(4), 674-701.

Moffitt, T. E. (2003). Life-course-persistent and adolescence-limited antisocial behavior: a 10-year research review and a research agenda. In B. B. Lahey, T. E. Moffitt, & A. Caspi

(Eds.), *Causes of conduct disorder and juvenile delinquency* (Vol. xiv, pp. 49-75). New York, NY: Guilford Press.

Muris, P., Meesters, C., & van den Berg, F. (2003). The Strengths and Difficulties Questionnaire (SDQ)--further evidence for its reliability and validity in a community sample of Dutch children and adolescents. *European Child and Adolescent Psychiatry, 12*(1), 1-8. doi:10.1007/s00787-003-0298-2

Nagin, D. S., & Tremblay, R. E. (2001). Parental and early childhood predictors of persistent physical aggression in boys from Kindergarten to High School *Archives of General Psychiatry, 58*(4), 389-394. doi:10.1001/archpsyc.58.4.389

Neale, M. C., & Cardon, L. R. (1992). *Methodology for Genetic Studies of Twins and Families*. Dorchecht, Belgium: Kluwer Academic Publications.

Neumann, C. S., & Pardini, D. (2014). Factor structure and construct validity of the self-report psychopathy (SRP) scale and the youth psychopathic traits inventory (YPI) in young men. *Journal of Personality Disorders, 28*(3), 419-433.

Pardini, D., & Fite, P. (2010). Symptoms of conduct disorder, oppositional defiant disorder, attention-deficit/hyperactivity disorder, and callous-unemotional traits as unique predictors of psychosocial maladjustment in boys: Advancing an evidence base for DSM-V. *Journal of the American Academy of Child & Adolescent Psychiatry, 49*(11), 1134-1144.

Plomin, R., DeFries, J. C., McClearn, G. E., & McGuffin, P. (2001). *Behavioral Genetics* (4th ed.). New York: Worth Publishers.

Poythress, N. G., Dembo, R., Wareham, J., & Greenbaum, P. E. (2006). Construct validity of the Youth Psychopathic Traits Inventory (YPI) and the Antisocial Process Screening Device

(APSD) with justice-involved adolescents. *Criminal Justice and Behavior, 33*(1), 26-55. doi:10.1177/0093854805282518

Poythress, N. G., & Skeem, J. L. (2006). Disaggregating psychopathy. *Handbook of psychopathy*, 172-192.

Raftery, A. E. (1995). Bayesian model selection in social research. *Sociological methodology, 25*, 111-164.

Rijsdijk, F., & Sham, P. C. (2002). Analytic approaches to twin data using structural equation models. *Briefings in Bioinformatics, 3*(2), 119-133.

Russo, M. F., & Beidel, D. C. (1994). Comorbidity of childhood anxiety and externalizing disorders: Prevalence, associated characteristics, and validation issues. *Clinical Psychology Review, 14*(3), 199-221.

Saudino, K. J., Ronald, A., & Plomin, R. (2005). The etiology of behavior problems in 7-year-old twins: Substantial genetic influence and negligible shared environmental influence for parent ratings and ratings by same and different teachers. *Journal of Abnormal Child Psychology, 33*(1), 113-130. doi:10.1007/s10802-005-0939-7

Schwarz, G. (1978). Estimating the Dimension of a Model. *Annals of Statistics, 6*(2), 461-464.

Scott, S., Knapp, M., Henderson, J., & Maughan, B. (2001). Financial cost of social exclusion: follow up study of antisocial children into adulthood. *British Medical Journal, 323*, 1-5. doi:10.1136/bmj.323.7306.191

Smedje, H., Broman, J.-E., Hetta, J., & von Knorring, A.-L. (1999). Psychometric properties of a Swedish version of the "Strengths and Difficulties Questionnaire". *European Child and Adolescent Psychiatry, 8*(2), 63-70.

Taylor, J., Loney, B. R., Bobadilla, L., Iacono, W. G., & McGue, M. (2003). Genetic and environmental influences on psychopathy trait dimensions in a community sample of male twins. *Journal of Abnormal Child Psychology, 31*(6), 633-645.

Thapar, A., Harrington, R., & McGuffin, P. (2001). Examining the comorbidity of ADHD-related behaviours and conduct problems using a twin study design. *The British Journal of Psychiatry, 179*(3), 224-229. doi:10.1192/bjp.179.3.224

Van Roy, B., Veenstra, M., & Clench-Aas, J. (2008). Construct validity of the five-factor Strengths and Difficulties Questionnaire (SDQ) in pre-, early, and late adolescence. *Journal of Child Psychology and Psychiatry, 49*(12), 1304-1312. doi:10.1111/j.1469-7610.2008.01942.x

van Widenfelt, B. M., Goedhart, A. W., Treffers, P. D., & Goodman, R. (2003). Dutch version of the Strengths and Difficulties Questionnaire (SDQ). *European Child and Adolescent Psychiatry, 12*(6), 281-289. doi:10.1007/s00787-003-0341-3

Viding, E., Blair, R. J., Moffitt, T. E., & Plomin, R. (2005). Evidence for substantial genetic risk for psychopathy in 7-year-olds. *Journal of Child Psychology and Psychiatry, 46*(6), 592-597. doi:10.1111/j.1469-7610.2004.00393.x

Viding, E., Fontaine, N. M., & Larsson, H. (2013). Quantitative genetic studies of psychopathic traits in minors: review and implications for the law. *Handbook on Psychopathy and Law*, 161.

Viding, E., Fontaine, N. M., & McCrory, E. J. (2012). Antisocial behaviour in children with and without callous-unemotional traits. *Journal of the Royal Society of Medicine, 105*(5), 195-200. doi:10.1258/jrsm.2011.110223

Viding, E., Frick, P. J., & Plomin, R. (2007). Aetiology of the relationship between callous-unemotional traits and conduct problems in childhood. *The British Journal of Psychiatry, 190*(49), s22-s38. doi:10.1192/bjp.190.5.s33

Viding, E., Jones, A. P., Frick, P. J., Moffitt, T. E., & Plomin, R. (2008). Heritability of antisocial behaviour at 9: do callous-unemotional traits matter? *Developmental Science, 11*(1), 17-22. doi:10.1111/j.1467-7687.2007.00648.x

Viding, E., & McCrory, E. J. (2012). Genetic and neurocognitive contributions to the development of psychopathy. *Development and Psychopathology, 24*(3), 969-983. doi:10.1017/S095457941200048X

Viding, E., Simmonds, E., Petrides, K., & Frederickson, N. (2009). The contribution of callous-unemotional traits and conduct problems to bullying in early adolescence. *Journal of Child Psychology and Psychiatry, 50*(4), 471-481.

Waschbusch, D. A., & Willoughby, M. T. (2008). Attention-deficit/hyperactivity disorder and callous-unemotional traits as moderators of conduct problems when examining impairment and aggression in elementary school children. *Aggressive Behavior, 34*(2), 139-153. doi:10.1002/ab.20224

Weisstein, E. W. (2016, April 22 2016). Covariance. Retrieved from http://mathworld.wolfram.com/Covariance.html