Genetic Contributions to Subtypes of Aggression

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Boys and girls may display different styles of aggression. The aim of this study was to identify subtypes of aggression within the Child Behavior Checklist (CBCL) aggression scale, and determine their characteristics for both sexes. Maternal CBCL ratings of 7449 7-year-old twin pairs were analyzed using principal components analyses to identify subtypes of aggression, and structural equation modeling to carry out genetic analyses. Two aggression subtypes were identified: relational and direct aggression. The correlation between these subtypes was .58 for boys and .47 for girls. Boys had higher mean scores for both subtypes of aggression, but sex differences were largest for direct aggression. For relational aggression, 66% of the variance was due to additive genetic influences, 16% to shared environment and 18% to nonshared environment. For direct aggression, additive genetic effects accounted for 53% of the variance in males and 60% in females, shared environment explained 23% of the variance in males and 13% in females, and nonshared environmental effects explained 24% of the variance in males and 27% in females. Covariance between the aggression subtypes was mostly accounted for by additive genetic (55% for boys, 58% for girls) and shared environmental influences (33% for boys, 30% for girls). Direct and relational aggression were both influenced by one underlying set of shared environmental factors, but only partly by the same genes (the genetic correlation was .54 for boys and .43 for girls). These findings may have implications for how aggressive behavior should be assessed in boys and girls.

A commonly used definition of aggression is 'behaviors that are intended to hurt or harm others' (Crick & Grotpeter, 1995). The word 'aggression' is often equated with physical violence, but clearly it covers many more aspects. Crick et al. (1997) note that childhood aggression has been mainly studied in boys, and that a type of behavior they call 'overt aggression' has been emphasized in this research. Aggression in girls and women has received relatively little attention. In general, girls are said to be less aggressive than boys (e.g., Stanger et al., 1997; Vierikko, 2003). However, it is important to note that girls probably display a different type of aggressive behavior to boys. Many subtypes of aggression have been distinguished through the years, such as verbal versus physical aggression, physical aggression towards others or towards oneself, aggression towards animals or objects, and reactive versus proactive aggression. But it is especially the distinction between indirect and direct aggression that has proved valuable for studying sex differences in aggression (Collett et al., 2003). Finnish researchers have found that girls use indirect aggression more than boys do (for a review, see Björkqvist, 1994). Using the Direct and Indirect Aggression Scales (DIAS; Björkqvist et al., 1992), Österman et al. (1998) measured three types of aggression: (direct) verbal, (direct) physical and indirect aggression. The latter was defined as 'social manipulation, attacking the target in circuitous ways'. Samples from Finland, Israel, Italy and Poland were studied. Children from three age groups (8, 11 and 15 years old) were rated by same-sex peers. They found that across nations, ethnic groups and age groups, indirect aggression was the type of aggression most used by girls, while physical aggression was used least. Among boys verbal and physical aggression were most common, while indirect aggression was used least. However, these differences were only proportional. Absolute differences between boys and girls were not discussed in this study.

Similar findings were reported by Crick et al. (1997) who measured 'overt' and 'relational' aggression in preschool children. The constructs of overt and relational aggression are similar to direct and indirect aggression as measured by Österman et al. (1998). To measure these traits, they used items from the Preschool Social Behavior Scale — Teacher Form (PSBS-T). Unlike Österman et al. (1998), Crick et al. (1997) report absolute differences between boys and girls. In preschool, teachers rated girls as more relationally

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aggressive, and boys as more overtly aggressive. Similar results were obtained in school-age children (Crick & Grotpeter, 1995). In this study, a peer nomination scale was used. The authors note that overt and relational aggression appear to be separate constructs, as many aggressive children show only one of the two types of aggressive behavior, and principal components analysis identified the two subtypes as separate factors. McEvoy et al. (2003) studied aggression in a sample of high-risk boys and girls. They report that boys use more direct than indirect aggression, while girls use more indirect than direct aggression, but they also found that boys are in fact more indirectly aggressive than girls. Tiet et al. (2001) report no sex differences in relational aggression.

A commonly used instrument to quantify aggression in children is the Child Behavior Checklist (CBCL; Achenbach, 1991). The CBCL measures problem behavior in children through parent ratings. The Dutch version of the CBCL/4–18 consists of 113 items, which form nine syndrome scales, including aggression (Verhulst et al., 1996). The aggression scale consists of 20 items. Many of these are not specifically aggression items (e.g., 'talks too much'). In fact, the scale includes mainly disruptive and oppositional behaviors (Collett et al., 2003). Some items concern physical aggressive behaviors (e.g., 'gets in many fights'). A few items may be considered verbal aggression items (e.g., 'argues a lot'). Furthermore, a number of items concern behaviors that might be considered aggressive, but not violent (e.g., 'bragging, boasting').

The construction of the CBCL and its cross-cultural validation between the United States and Dutch populations is described by Achenbach (1991; Achenbach & McConaughy, 1997) and Verhulst et al. (1996). The syndrome is stable across both cultures (Verhulst et al., 1996). Across informants and age groups, boys have higher scores on CBCL aggression than girls (Hudziak et al., 2003; Stanger et al., 1997; Verhulst et al., 1996).

The literature discussed above indicates that aggression in boys and girls may differ in many aspects. These differences might arise because of environment, but they may also be influenced by genetic differences between males and females. Previous research on CBCL aggression has indicated that aggression is a highly heritable trait. Studies of sex differences in heritability have been somewhat inconsistent. These inconsistencies may in part be explained by the use of different raters and age differences. For example, in a Dutch sample, Hudziak et al. (2003) found heritability estimates between 60% and 70% at age 7, as rated by mothers, fathers and teachers. At this age, there were no sex differences in heritability. At age 3, heritability was higher for girls (67%) than for boys (51%), as rated by the father, whereas at age 10, heritability was somewhat higher for boys (71%) than for girls (52%), as rated by the mother. In a study of 12-year-old Dutch children, Bartels et al. (2003) found heritabilities of 61% in boys and 54% in girls, as rated by the mother, and 60% in boys and 48% in girls, as rated by the father. Van Beijsterveldt et al. (2003) used overlapping samples of Dutch twins in a longitudinal design. They studied children at age 3, 7, 10 and 12 years, and across these ages they found average heritabilities of 64% for boys and 57% for girls. Eley et al. (1999) found heritabilities of 62% in boys and 75% in girls for CBCL aggression by both parents in a Swedish sample of twins aged 7 to 9 years.

In summary, previous studies have shown considerable sex differences in CBCL aggression scores and a high heritability. When aggression is assessed with instruments other than the CBCL, boys and girls typically display different styles of aggression (Crick et al., 1997; Crick & Grotpeter, 1995; McEvoy et al., 2003; Österman et al., 1998). It would be interesting to see whether it is possible to distinguish subtypes of aggressive behavior within the CBCL aggression scale, and to study possible sex differences in mean scores and genetic architecture for these subtypes. A second question is to what extent these subtypes are influenced by the same genes and environmental factors. Therefore, in this study we aim to identify subtypes of aggressive behavior within the CBCL, and explore their genetic and environmental characteristics.

Methods

Subjects

Data on aggression were available for 7449 7-year-old twin pairs whose parents had enrolled them with the Netherlands Twin Registry (NTR), kept by the Department of Biological Psychology in Amsterdam. Data collection was part of a large ongoing longitudinal study. Around 40% to 50% of multiple births in the Netherlands are registered by the NTR (Boomsma, 1998; Boomsma et al., 2002).

The CBCL (Achenbach, 1991) was sent to the twins' parents by mail. Nonresponders received a reminder after 2 or 3 months, and if finances permitted, those who did not respond were contacted by telephone. This procedure resulted in a response rate of approximately 80%. For this study, data from the 1986–1996 birth cohorts were used (7595 twin pairs). Excluded from the analyses were 146 twin pairs, as at least one of the twins had a disease or handicap that severely interfered with daily functioning. This resulted in a sample of 7449 twin pairs. For 776 twin pairs, zygosity was determined based on blood or DNA analyses. For the remaining twin pairs, zygosity was determined from questionnaires (Rietveld et al., 2000). The sample consisted of 1247 monozygotic male (MZM), 1251 dizygotic male (DZM), 1425 monozygotic female (MZF) and 1168 dizygotic female (DZF) twin pairs. There were 1215 opposite-sex (DOS) twin pairs of which the first-born twin was male (DOSMF), and 1136 pairs of which the first-born twin was female (DOSFM). Seven pairs were excluded because zygosity

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was unknown. Of the total sample, 49% of the subjects were boys and 51% were girls.

Measures

Aggression was measured with the Dutch version of the CBCL/4–18 (Achenbach, 1991; Verhulst et al., 1996), a questionnaire consisting of 113 items concerning problem behavior in children 4 to 18 years old. Mothers were asked to rate the behavior of their children during the past 6 months. All behaviors were rated on a 3-point scale: 0 = *not true*, 1 = *somewhat or sometimes true*, and 2 = *very true or often true*. The aggression scale consists of 20 items, which are listed in Table 1.

Statistical Analyses

Principal Components Analysis

To find out whether subtypes of aggression exist within the CBCL aggression scale, principal components analyses (PCA) with Varimax rotation were performed in SPSS 11.5. (2002). Factor scores and sum scores were obtained for the subscales. A square root transformation was applied to the scores to approach normality. The transformed sum scores for each aggression subtype were used in the genetic analyses.

Genetic Modeling

Using the twin method, the amount of variance due to additive genetic (A), shared environmental (C) and nonshared environmental (E) influences on a trait and the influences of A, C and E on the covariance between two traits can be estimated by looking at the resemblance between twins (Boomsma et al., 2002). The influence of A, C and E on variances and covariance was estimated through structural equation modeling, using the statistical program Mx (Neale et al., 2003). The goodness-of-fit of alternative models was compared by likelihood ratio tests. When a simplified model results in a significant increase in chi-square compared to a more complex model, this suggests that the more complex model fits the data better and should be preferred over the simpler model. When there is no significant difference in fit, the most parsimonious model is preferred. An additional criterion for model comparison is Akaike's Information Criterion (AIC), which is based on both chi-square and parsimony, by taking $\chi^2 - 2df$ (Akaike, 1987).

Initially, a saturated model was used to calculate twin correlations and cross-twin cross-trait correlations, and to test for differences in means and variances between first-born and second-born twins, between boys and girls, and between zygosity groups. Next, a bivariate Cholesky decomposition was used to estimate the variance components for two aggression subtypes and the influence of genetic and environmental influences on their covariance (Figure 1). Because same-sex DZ twins share on average 50% of their segregating genes, correlations between their genotypic values were fixed at .5. By constraining correlations in opposite-sex twins to be .5, we tested whether the same genes are expressed in boys and girls. Variance and covariance estimates in boys and girls were equated to test whether there are sex differences in the relative contributions of A, C and E. To see whether each of these components significantly contributed to the total variance and/or covariance, we tested whether dropping them from the model resulted in a deterioration of fit. The results from the bivariate analysis were used to calculate genetic and environmental correlations between the variables, by standardizing the variance–covariance matrices for each of the variance components. This indicates to what extent two traits are influenced by the same genes and environmental factors.

Table 1

Subtypes of the CBCL Aggression Scale

Subtype 1: Relational aggression		Subtype 2: Direct aggression	
3.[a]	Argues a lot	16.	Cruelty, bullying or meanness to others
7.	Bragging, boasting	20.	Destroys his/her own things
19.	Demands a lot of attention	21.	Destroys things belonging to his/her family or others
22.	Disobedient at home	37.	Gets in many fights
23.	Disobedient at school	57.	Physically attacks people
27.	Easily jealous	97.	Threatens other people
68.	Screams a lot		
74.	Showing off or clowning		
86.	Stubborn, sullen or irritable		
87.	Sudden changes in mood or feelings		
93.	Talks too much		
94.	Teases a lot		
95.	Temper tantrums or hot temper		
104.	Unusually loud		

Note: a = numbers refer to items numbers of the CBCL.

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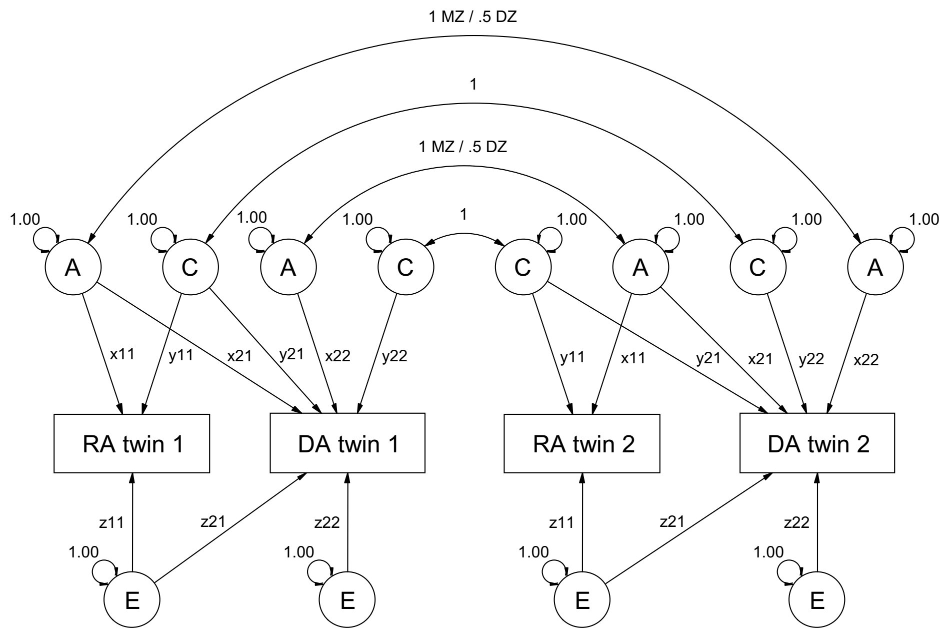

Figure 1

Bivariate Cholesky decomposition.

RA = relational aggression; DA = direct aggression.

Results

PCA with varimax rotation were carried out for first- and second-born twins (because of the nonindependence of twin data), and for boys and girls. Scree plots pointed towards a two-factor solution. In most groups, four eigenvalues of greater than 1 were found. However, considering the results of previous research (see Achenbach et al., 2003) and the content of the items, a two-factor solution appeared to be the most plausible one. The first factor explained between 30% and 34% of the variance across groups, and the second factor explained another 7% to 8%. For all items except one (item 23, 'disobedient at school'), the classification was the same in boys and girls, and first- and second-born twins. Item 23, which loaded on both subtypes, was assigned to component 1, because the overall content of this component was most similar to the content of this specific item.

The first component identified consisted of 14 items, describing mainly oppositional behavior problems, as they reflect hostile, negativistic and defiant behaviors (American Psychiatric Association, 1994). It also contained a few items that describe loud, dominant, but not necessarily oppositional behavior (see Table 1). This factor will be referred to as relational aggression. The second component consisted of six items which describe more pure, direct aggressive behavior. This factor will be referred to as direct aggression.[1]

For both variables, sum scores were calculated. High correlations (around .9) were found between the sum scores and the factor scores calculated by SPSS. Therefore the sum scores of the two identified subfactors were used as the new variables in the genetic analyses. There was a correlation between the two variables of .58 in boys and .47 in girls. Means and variances of the untransformed sum scores for both factors are described in Table 2. Average direct aggression scores are much lower than relational aggression scores, partly because the direct aggression scale consists of fewer items, but also because endorsement of these particular items was lower, which may be an indication of the severity of these problem behaviors as compared to the relational aggression items.

Saturated Model

First, a saturated model was used to test for differences in means and variances between (1) first- and second-born twins; (2) MZ, DZ and DOS twins; and (3) boys and girls. For relational aggression, differences in means were found for birth order, $\Delta\chi^2(6) = 75.542$, $p < .001$, zygosity, $\Delta\chi^2(8) = 24.349$, $p = .002$, and sex, $\Delta\chi^2(6) = 390.538$, $p < .001$. No difference in means was found for MZ and DZ same-sex pairs, but boys and girls from opposite-sex pairs had lower means than boys and girls from same-sex pairs. First-born twins had slightly higher mean scores than second-born twins, and boys had higher scores than girls. No differences in variances were found for relational aggression.

For direct aggression, differences in means were found for zygosity, $\Delta\chi^2(8) = 50.911$, $p < .001$, and sex, $\Delta\chi^2(6) = 772.913$, $p < .001$, but not for birth order, $\Delta\chi^2(6) = 8.609$, $p = .197$. Again, no difference in means was found for MZ and DZ same-sex pairs, but boys and girls from opposite-sex pairs had

Table 2

Untransformed Mean Scores and Variances, for First-Born and Second-Born Twins Separately

	First-born			Second-born		
Relational aggression	*N*	Mean	Var.	*N*	Mean	Var.
MZM	1238	7.30	27.18	1238	6.87	25.97
DZM	1246	6.88	27.68	1246	6.42	24.38
MZF	1413	5.50	22.00	1413	5.19	21.20
DZF	1158	5.50	21.11	1158	5.27	20.78
DOSMF	1200	6.70	26.49	1200	4.70	18.79
DOSFM	1122	5.14	22.08	1122	6.19	24.93
Direct aggression	*N*	Mean	Var.	*N*	Mean	Var.
MZM	1238	1.01	2.26	1238	0.98	2.12
DZM	1246	0.96	2.43	1246	0.91	2.20
MZF	1413	0.44	1.05	1413	0.41	0.93
DZF	1158	0.38	0.79	1158	0.45	1.09
DOSMF	1200	0.83	1.92	1200	0.29	0.59
DOSFM	1122	0.30	0.72	1122	0.76	1.71

Note: MZM = monozygotic male; DZM = dizygotic male; MZF = monozygotic female; DZF = dizygotic female; DOSMF = opposite-sex twins, male born first; DOSFM = opposite-sex twins, female born first.

lower mean scores than boys and girls from same-sex pairs. For direct aggression, sex differences were larger than for relational aggression, with boys having mean scores over twice as high as girls (see Table 2). Variances differed across groups, with same-sex twins having larger variances than DOS twins, $\Delta\chi^2(8) = 83.123$, $p < .001$, and boys having larger variances than girls, $\Delta\chi^2(6) = 653.856$, $p < .001$. The difference for birth order was only marginally significant, $\Delta\chi^2(6) = 13.443$, $p = .037$.

Twin correlations and cross-trait cross-twin correlations are reported in Table 3. MZ twin and cross-trait cross-twin correlations were higher than DZ correlations. They were less than twice as high, however, suggesting that both subtypes and the covariance between them might be influenced by genes and by shared environmental influences. Based on the twin correlations, there was no evidence for dominance effects. Therefore, an ACE model was tested. The pattern of twin correlations in Table 3 also shows that same-sex DZ and DOS correlations are very similar and that therefore it is likely that the same genes and/or common environmental influences are expressed in boys and girls.

Genetic Model Fitting

A bivariate Cholesky decomposition (Figure 1) was used to estimate genetic, shared and nonshared

Table 3

Twin and Cross-Correlations (95% Confidence Intervals) for Relational and Direct Aggression by Zygosity

	Relational aggression	Direct aggression	RA–DA Twin 1	RA–DA Twin 2	RA twin1–DA twin2	DA twin1–RA twin2
MZM	.83	.77	.62	.58	.54	.53
	(.82–.85)	(.75–.79)	(.58–.65)	(.54–.61)	(.50–.57)	(.49–.56)
DZM	.50	.51	.62	.59	.35	.40
	(.46–.54)	(.47–.55)	(.59–.65)	(.55–.62)	(.31–.40)	(.36–.45)
MZF	.82	.75	.52	.48	.44	.45
	(.80–.83)	(.73–.77)	(.48–.56)	(.44–.52)	(.40–.48)	(.41–.49)
DZF	.48	.45	.45	.49	.29	.28
	(.44–.52)	(.41–.50)	(.40–.49)	(.44–.53)	(.24–.34)	(.22–.33)
DOSMF	.49	.37	.58	.43	.24	.35
	(.45–.53)	(.32–.42)	(.54–.61)	(.38–.47)	(.19–.29)	(.31–.40)
DOSFM	.49	.42	.46	.54	.28	.29
	(.44–.53)	(.37–.46)	(.42–.51)	(.50–.58)	(.22–.33)	(.24–.34)

Note: MZM = monozygotic male; DZM = dizygotic male; MZF = monozygotic female; DZF = dizygotic female; DOSMF = opposite-sex twins, male born first; DOSFM = opposite-sex twins, female born first; RA = relational aggression; DA = direct aggression.

Table 4

Bivariate Model-Fitting Results: Significance of Sex Differences and A, C and E Variance/Covariance Components

Sex differences		–2LL	*df*	AIC	Compared with model	χ^2	*Δ df*	*p*
1	ACE sex differences[1]	62,356.41	29469	3418.407				
2	ACE no heterogeneity	62,356.42	29470	3416.418	1	0.01	1	.916
3	$ACE_m = ACE_f$[2] variance RA[3]	62,361.91	29473	3415.908	2	5.49	3	.139
4	$ACE_m = ACE_f$ variance DA[3]	62,521.01	29473	3575.006	2	164.59	3	.000
5	$ACE_m = ACE_f$ covariance	62,525.34	29473	3579.341	2	168.92	3	.000
Variance: Relational aggression								
6	drop A	63,238.18	29474	4290.178	3	876.27	1	.000
7	drop C	62,455.68	29474	3507.677	3	93.77	1	.000
Factor-specific variance: Direct aggression								
8	drop A males	62,507.54	29474	3559.542	3	145.63	1	.000
9	drop C males	62,363.20	29474	3415.200	3	1.29	1	.256
10	drop A females	62,541.81	29474	3593.808	3	179.90	1	.000
11	drop C females	62,362.87	29474	3414.866	3	0.96	1	.328
Covariance								
12	drop A males	62,610.12	29474	3662.115	3	248.21	1	.000
13	drop C males	62,436.39	29474	3488.388	3	74.48	1	.000
14	drop A females	62,516.51	29474	3568.510	3	154.60	1	.000
15	drop C females	62,415.50	29474	3467.499	3	53.59	1	.000
16	Best model[4]	62,363.794	29475	3413.794	3	1.89	2	.389

Note: 1 = Both genetic heterogeneity and sex differences in the magnitude of A, C and E.
2 = ACE_m = variance components for males; ACE_f = variance components for females.
3 = RA = relational aggression; DA = direct aggression.
4 = No heterogeneity and no factor specific C for males or females.

environmental influences on the two subtypes and the overlap between them.

The results are listed in Table 4. The first model tested was a full ACE model with separate variance components for males and females. The genetic covariance for opposite-sex twins was allowed to differ from .5. Fixing this parameter at .5 (model 2) did not result in a significant deterioration of the model, indicating that the same genes are of importance in boys and girls, $\Delta\chi^2 = .01$, $\Delta df = 1$, $p = .916$. The magnitude of A, C and E could be equated across sex for the variance of relational aggression, path coefficients x_{11}, y_{11} and z_{11} in Figure 1; $\Delta\chi^2(3) = 5.49$, $p = .139$, but not the variance of direct aggression, path coefficients x_{22}, y_{22} and z_{22}; $\Delta\chi^2(3) = 164.59$, $p < .001$, or the covariance between the two subtypes, path coefficients x_{21}, y_{21} and z_{21}; $\Delta\chi^2(3) = 168.92$, $p < .001$. Next, the influence of A, C and E on the variance and covariance was tested for significance. In both sexes, A and C significantly contributed to the variance and covariance of relational and direct aggression. The factor-specific common environmental variance for direct aggression could be dropped from the model without decreasing model fit, $\chi^2(1) = 1.13$, $p = .287$ for boys, $\chi^2(1) = 1.06$, $p = .304$ for girls. There was, however, a significant factor-specific genetic variance. The genetic correlations (r_g) of .54 for boys and .43 for girls indicate that relational and direct aggression are only partly influenced by the same genes.

For relational aggression, heritability was estimated at 66%, 16% of the variance was explained by shared environmental factors and 18% by nonshared environmental factors. For direct aggression in boys, 53% of the variance was explained by genetic factors, 23% by shared environmental factors, and 24% by nonshared environmental factors. For girls, this was 60%, 13% and 27%, respectively (see Table 5).

For boys a correlation of .58 was found between relational and direct aggression scores. For girls, this correlation was .47. In boys, 55% of the correlation was explained by genetic factors, 33% by shared environmental factors, and 12% by nonshared environment. For girls this was 58%, 30% and 12%, respectively.

Discussion

The aim of this study was to identify subtypes of aggression within the CBCL aggression scale, and study their characteristics in terms of sex differences and genetic and environmental influences. PCA identified two factors within the aggression scale of the CBCL/4–18. The first factor consists of a set of items that is best described as 'relational aggression'. The second factor is best described as 'direct aggression'.

Table 5

Variance Decomposition for Relational and Direct Aggression, Contribution of the Variance Components to the Correlation Between the Two Subtypes in Boys and Girls, and the Genetic and Environmental Correlations Between the Two Subtypes

	A (95% CI)	C (95% CI)	E (95% CI)
Variance components RA ♂♀	66% (62–70)	16% (12–20)	18% (17–19)
Variance components DA ♂	53% (45–61)	23% (15–30)	24% (22–26)
Variance components DA ♀	60% (53–66)	13% (07–19)	27% (25–29)
Contribution to covariance ♂	55% (48–63)	33% (26–39)	12% (10–14)
Contribution to covariance ♀	58% (48–67)	30% (22–38)	12% (09–14)
r_g and r_e ♂	.54 (.50–.58)		.34 (.29–.38)
r_g and r_e ♀	.43 (.38–.48)		.25 (.21–.30)

Note: RA = relational aggression; DA = direct aggression; r_g = genetic correlation; r_e = nonshared environmental correlation.

This finding is supported by previous research. In a study by Achenbach et al. (2003), experts rated CBCL items for consistency with the diagnostic categories of the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV; American Psychiatric Association, 1994), thus combining empirical and diagnostic approaches. Five out of six items of the direct aggression factor were found to describe symptoms of conduct problems, while none of the items of the first factor did. Five of the items belonging to the relational aggression factor were found to be consistent with oppositional defiant behavior problems, and two of them were consistent with attention deficit hyperactivity problems. The other aggression items did not meet the authors' criteria for consistency with DSM categories. Thus, the direct aggression factor resembles a fairly specific DSM-IV diagnosis of conduct disorder, whereas the relational factor resembles oppositional defiant disorder. Another indication that we are dealing with separate subtypes is the fact that mean scores on both factors are very different. Mean scores on factor 2 are much lower than those on factor 1. This may indicate that the direct aggression factor describes problem behaviors which are less common and perhaps more serious than the behaviors captured by the relational aggression factor.

Based on the literature, we would expect boys to have higher scores on relational aggression (American Psychiatric Association, 1994) but especially on the direct aggression factor, since direct aggression has been found to be the aggressive style most used by boys and least used by girls (Österman et al., 1998), and boys are usually found to be more directly aggressive than girls (Crick et al., 1997; Crick & Grotpeter, 1995; McEvoy et al., 2003; Österman et al., 1998). This is indeed what our data suggest. Because mean direct aggression scores are quite low, absolute sex differences do not appear to be large at first sight, but relative sex differences are much larger for direct aggression than for relational aggression.

For both aggression factors we found a moderate to high heritability. For relational aggression, no sex differences were found in the relative importance of genes, shared environment and nonshared environment. For direct aggression, however, small but significant sex differences were detected. The same sets of genes appeared to influence both factors in boys and girls.

In both sexes, a large part of the correlation between the two factors can be explained by genetic and shared environmental influences. The influence of nonshared environment on the correlation is modest. Common environmental influences are entirely shared by the two factors. However, only the genes that influence the factors overlap only partly, which is reflected in a genetic correlation (r_g) of .54 for boys and .43 for girls.

This less than perfect overlap for genetic influences suggests that relational and direct aggression are indeed separate constructs. This finding may have important implications for intervention and research strategies. Distinct intervention programs may be appropriate and comorbidity of the two factors should be investigated. The distinction between the various subtypes of aggression is especially important in the search for the genes that influence this complex behavioral trait. When studying physical aggression, the use of animal models is a realistic option. For example, attack latency in mice has been suggested as a model for physical violence in humans (Sluyter et al., 2003). However, it is likely that other subtypes (such as relational aggression) will require a different approach. As subtypes of aggression might be more closely related to the functioning of specific biological pathways than aggression in general, using more precise measures may ultimately increase our chances of success in the search for genes.

Interestingly, aggression scores of opposite-sex twins were lower than those of same-sex twins (see Table 2). This was especially true for direct aggression, and to a lesser extent for relational aggression. One possible explanation for this observation is that having a female co-twin is a protective factor for boys. The fact that girls from opposite-sex twins also have lower aggression scores could then be explained by a rater contrast effect (Rietveld et al., 2003). Rater contrast effects, however, are characterized by inflated

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variances in MZ and DZ twins (the effect being greatest in MZ twins), and by large differences between MZ and DZ correlations (Rietveld et al., 2003). This difference in variances is consistent with the pattern of variances we found for direct aggression, but not relational aggression (see Table 2). Furthermore, we did not find large differences between MZ and DZ correlations. Therefore, we do not expect rater contrast to be of great importance.

Only maternal ratings were used to study aggression. Previous research has shown that ratings by fathers and teachers can supply additional information which is rater-specific (Bartels et al., 2003). For a more complete picture of aggression, it would be useful to consider these other sources of information as well.

Another limitation is that, even after transformation, especially the direct aggression data remained significantly skewed as these problem behaviors are not very common in a nonclinical population. A recent paper by Derks et al. (2004) shows that this may result in a correct estimation of A, but an underestimation of C and an overestimation of E. Therefore, some caution is needed when interpreting these results.

The CBCL aggression scale measures two subtypes of aggression: direct and relational aggression. The relational aggression scale identified within the CBCL bears some resemblance to indirect aggression as described by Björkqvist et al. (1992), in that it concerns a nonviolent and nonphysical form of aggression. However, Björkqvist's indirect aggression mostly consists of manipulative behaviors, not meant to be obvious to parents or teachers. The relational aggression scale of the CBCL does not include this type of behavior. A peer report version of the CBCL, called the Twin Youth Report, is currently under development (J. J. Hudziak, personal communication, March 2005). This instrument may allow more reliable assessment of relational aggression, as peers have access to aspects of each other's social behavior that are not visible to parents or teachers. It would also create the possibility of extending our measure with additional items describing aspects of relational aggression that are hard to measure in a teacher or parent report design due to the covert nature of some relational aggressive behaviors (Österman et al., 1998).

An important next step is to pursue these analyses both cross-sectionally and longitudinally. At 7 years of age, sex differences are apparent in both factors, but they are much larger for direct aggression. This is not unlikely to change over the years. Mean scores on the CBCL aggression scale tend to decline with age (Hudziak et al., 2003; Stanger et al., 1997), and as children grow up and reach adolescence we might expect their preferred styles of aggression to change, which might also affect patterns of sex differences. Therefore, an important research direction is to test the cross-sectional factor and genetic structure of the two subtypes at ages 10 and 12 years, and then to perform longitudinal analyses as we have done with the broad aggression scale in the past (van Beijsterveldt et al., 2003).

This idea is particularly germane to the study of relational and direct aggression across adolescents and into early adulthood. Indeed in the Adult Self-Report (ASR), the aggression items of the CBCL segregate into two separate syndromes in adulthood. These are the intrusive and aggressive syndromes. Many of the relational aggression items load on the intrusive factor that is marked by relational problems, but without fighting or physical aggression. The remaining items from the CBCL aggressive syndrome map on the adult aggressive syndrome (Achenbach & Rescorla, 2003). Although no longitudinal analyses linking childhood to adulthood have yet been completed, it is important to determine if the factors we have identified in this research continue to develop into adulthood where there is a clear separation between these two patterns.

Endnote

1 Note that these subtypes are not related to relational aggression as described by Crick et al. (1997) or direct aggression as described by Björkqvist et al. (1992).

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