Genetic and Environmental Contributions to Stability and Change in Children's Internalizing and Externalizing Problems

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ABSTRACT

Objective: To estimate genetic, shared environmental, and nonshared environmental contributions to stability and change in internalizing and externalizing problems. **Method:** Maternal Child Behavior Checklist ratings were obtained for 3,873 twin pairs at age 3 and 1,924 twin pairs at age 7. For 1,575 twin pairs, ratings were available at both ages. **Results:** For Internalizing/Externalizing ratings, genetic, shared, and nonshared environmental factors explained about 59/51%, 10/30%, and 31/19% of the variance at age 3, and 40/52%, 31/32%, and 29/16% of the variance at age 7. The phenotypic correlation of $r = 0.38/0.54$ between problems assessed at 3 and 7 years of age was explained for 66/55% by genetic factors, for 23/37% by shared environmental factors, and for 11/8% by nonshared environmental factors. The genetic, shared environmental, and nonshared environmental correlations between ages 3 and 7 were 0.51/0.57, 0.47/0.66, and 0.13/0.24, respectively. **Conclusions:** Genetic and shared environmental factors were most important for the stability of Internalizing and Externalizing Problems between ages 3 and 7. Nonshared environmental factors were mainly age-specific. For Internalizing Problems, shared environment may become more important from early to middle childhood. *J. Am. Acad. Child Adolesc. Psychiatry,* 2003, 42(10):1212–1220. **Key Words:** longitudinal study, heritability, problem behaviors, twins, Child Behavior Checklist.

Problem behaviors tend to persist over time. In his review of longitudinal studies, Koot (1995) concluded that one third to one half of the children with deviant behavior remained deviant after 2 to 6 years. Caspi et al. (1996) found that a difficult temperament at age 3 was even associated with *DSM-III* diagnoses at age 21. However, many children also change across time. Koot's results (1995), for instance, also imply that two thirds to one half of the children improve. The development of problem behaviors is therefore best characterized by both continuity and change.

To obtain a better understanding of the genetic and environmental contributions to continuity and change in children's problem behaviors, studies with genetically informative samples, such as twins, are important. These studies enable researchers to examine the extent to which behaviors are influenced by persistent or age-specific genetic and environmental factors. Persistent factors have effects on the assessments obtained at every age and account for continuity in problem behaviors. The age-specific factors influence the behaviors at a specific age only and account for changes in children's problem behaviors. In quantitative genetic studies a distinction is usually made between environmental influences that are shared by children growing up in the same family versus environmental factors that affect children within the same family differently. Parental

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rearing practices or the family's socioeconomic status are examples of possible shared environmental influences. Accidents, differential parental treatment, or peer group influences are examples of possible nonshared environmental influences.

Four studies have examined the genetic and environmental contributions to continuity and change in children's problem behaviors. Schmitz et al. (1995) analyzed Child Behavior Checklist (CBCL) (Achenbach, 1991, 1992) ratings from a sample of 95 twin pairs that were obtained at ages 2 and 7. For Internalizing Problems, shared environmental factors accounted for most of the continuity, while genetic influences were mainly age-specific. The opposite was found for Externalizing Problems, showing persistent genetic and age-specific shared environmental effects. The second study was conducted by van den Oord and Rowe (1997). They studied maternal Behavior Problems Index (Peterson and Zill, 1986) ratings of 436 pairs of full siblings, 119 pairs of half siblings, and 122 pairs of cousins assessed at ages 4 to 6, 6 to 8, and 8 to 10 years. Continuity in problem behaviors was entirely explained by genetic and shared environmental factors. Nonshared environmental factors showed only age-specific effects. Third, van der Valk et al. (1998a) analyzed the CBCL (Achenbach, 1991) obtained at two assessment points, 3 years apart, from a sample of 75 pairs of adopted biological siblings, 154 pairs of adopted nonbiological siblings, and 1,080 adopted singletons, initially aged 10 to 15 years. The stability of Externalizing Problems was influenced mostly by genetic factors, showing about equal influences of persistent and age-specific factors. For Internalizing Problems, nonshared environmental factors mostly explained the stability, again showing almost equal persistent and age-specific influences. Finally, O'Connor et al. (1998) followed 405 families over a 3-year interval. Their sample consisted of same-sex monozygotic (MZ) and dizygotic twins (DZ) plus full, half, and unrelated siblings who were between 10 and 18 years of age at the time of the first assessment. The continuity of antisocial symptoms was for 54% explained by genetic influences and for 30% by shared environmental influences. For depressive symptoms, genetic influences accounted for 64% and nonshared environmental influences for 36% of the continuity. In sum, although these studies pertain to different samples and different age intervals, relatively large genetic effects on the stability of problem behaviors are identified consistently. The nature of the shared and nonshared environmental effects is less clear, showing contributions to stability in some studies and only age-specific effects in others.

In the present study, maternal CBCL ratings (Achenbach, 1991, 1992) were obtained for a large twin sample consisting of 3,873 three-year-old and 1,924 seven-year-old twin pairs. For 1,575 twin pairs, ratings were available at both ages. We focused on two broad-band groupings of problem behaviors: Internalizing and Externalizing Problems. Internalizing Problems are characterized by feelings of inferiority, self-consciousness, social withdrawal, shyness, anxiety, hypersensitivity, depression, and somatic complaints such as headaches, stomachaches, or back pains. Externalizing Problems are characterized by antisocial, aggressive, and other undercontrolled behaviors. This distinction between the two groupings is not specific for the CBCL but, albeit with other labels, reflects that problem behaviors in childhood co-occur in specific patterns.

Whereas narrowly defined syndromes may differ across ages, a major advantage of focusing on Internalizing and Externalizing Problems is that similar groupings are found in preschool and school-age children (Achenbach, 1991, 1992; Koot et al., 1997). This facilitates our longitudinal study. Furthermore, the validity of the CBCL Internalizing/Externalizing scales has been supported by a wide variety of studies (Achenbach, 1991, 1992; De Groot et al., 1994; Hartman et al., 1999). From a developmental perspective the interval between ages 3 and 7 is interesting because it is characterized by many physical, cognitive, social, and emotional changes. For example, the interval contains the transition to school, implying that children must learn to cope with academic demands, adjust to the daily routine of school, and develop relations with classmates (Barth and Parke, 1993; Ladd and Price, 1987). In contrast to middle childhood, which may be a relatively stable period in which mainly the same genes and environmental factors seem to account for variation in problem scores (van den Oord and Rowe, 1997), the nature and relative importance of genetic and environmental factors could very well change during the transition from preschool to school age. It may be important to stress that results from our longitudinal analyses pertain to a hypothetical "average" individual. Thus, if continuity would be caused by a mix of genetic and environmental factors, the persistence of problem behaviors could still be completely environmental in some individuals and completely genetic in others.

METHOD

Sample

All participants were members of the Netherlands Twin Registry (Boomsma et al., 1992). The accuracy of zygosity determination by questionnaire items is described by Rietveld et al. (2000). A detailed description of sample collection, zygosity determination, means, and standard deviations of CBCL scales for age 3 can be found in van der Valk et al. (1998b, 2001), and for age 7 in van der Valk et al. (2003). The total sample consisted of 3,873 twin pairs at age 3 and 1,924 twin pairs at age 7. For 1,575 twin pairs, ratings were available at both ages. This group could further be subdivided into 292 monozygotic males (MZM), 288 dizygotic males (DZM), 311 monozygotic females (MZF), 252 dizygotic females (DZF), and 495 dizygotic opposite sex (DOS) twin pairs.

Measures

The CBCL is a parental rating scale for assessing behavioral and emotional problems in 2- and 3-year-olds (CBCL/2–3) (Achenbach, 1992) or 4- to 18-year-olds (CBCL/4–18) (Achenbach, 1991). The Dutch CBCL/2–3 Internalizing/Externalizing scales (Koot et al., 1997) used in this study differ slightly from those reported by Achenbach (1992). The Internalizing scale comprised the Anxious and Withdrawn/Depressed syndromes; the Externalizing scale comprised the Oppositional, Aggressive, and Overactive syndromes. With respect to the factor structure of the CBCL/4–18, De Groot et al. (1994) showed that there were few differences between American and Dutch samples. The Internalizing/Externalizing scales for the CBCL/4–18 were therefore scored according to the American manual (Achenbach, 1991). The Internalizing scale consists of the Withdrawn, Somatic Complaints, and Anxious/Depressed syndrome scales. The Externalizing scale consists of the Rule-Breaking Behavior (previously labeled Delinquent Behavior) and Aggressive Behavior syndrome scales.

Data Analysis

To estimate the genetic, shared environmental, and nonshared environmental contributions to persistency and change in Internalizing and Externalizing Problems at ages 3 and 7, we used the model depicted in Figure 1. This model uses the standard assumptions and principles of twin studies (Neale and Cardon, 1992; Plomin et al., 1990). Latent (unobserved) factors are in circles; observed variables are in squares. The A's refer to the additive genetic factors, the C's to the common or shared environmental factors, and the E's to the nonshared environmental factors. The genetic and environmental factors that influence problem scores at both ages are not subscripted (i.e., A, C, and E). These are the factors that contribute to the continuity of problem behaviors. The factors subscripted 3 or 7 are age-specific (A_3, C_3, E_3, A_7, C_7, and E_7). For statistical purposes the genetic and environmental influences are assumed to be additive and independent. To compute the genetic and environmental contributions, we fixed all arrows in Figure 1 to one and estimated the variances of the latent factors.

The estimates of effects in Figure 1 are essentially based on a comparison of the resemblances between MZ and DZ twins. MZ twins are genetically identical and usually reared together. Differences found between them must therefore be nongenetic and of the nonshared environmental type (E). DZ twins are no more similar genetically than normal siblings. As with MZ twins, they are usually reared together and the influence of shared environmental factors (C) can be taken as essentially similar. Hence, if MZ twins are more similar than DZ twins, this must indicate genetic (A) influences.

We fitted the model with Mx (Neale et al., 1999), using a maximum likelihood estimation procedure for raw data. This esti-

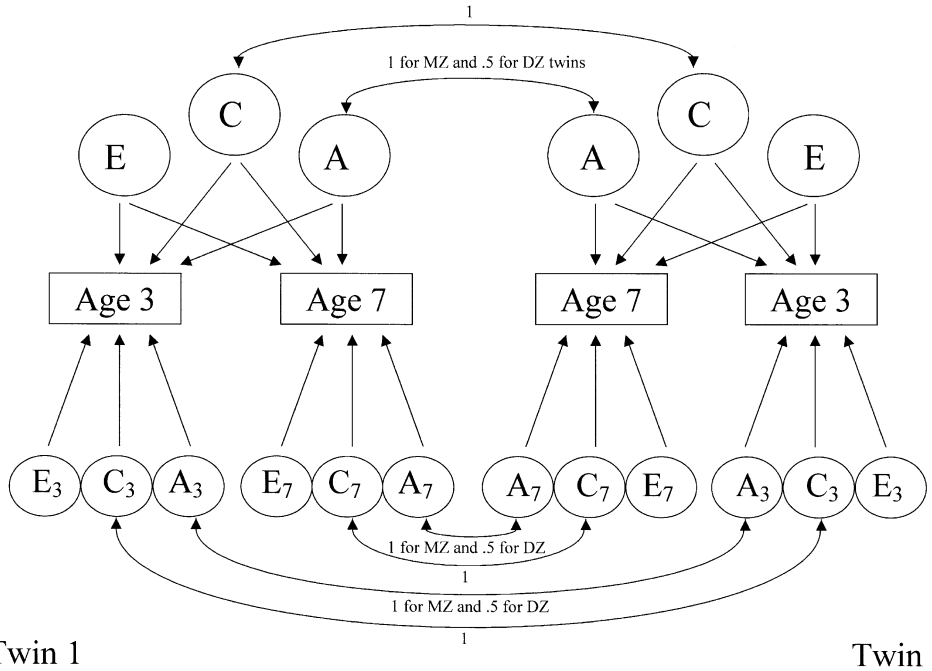

Fig. 1 Twin model for estimating genetic and environmental contributions to stability and change in problem behaviors at ages 3 and 7. MZ = monozygotic; DZ = dizygotic.

mation technique can handle incomplete data and allowed us to retain twin pairs who had not reached the age of 7 or had missing data. Raw maximum likelihood yields a goodness of fit index called log-likelihood, which cannot be interpreted itself. Twice the difference between the log-likelihood of a full model minus the log-likelihood of a submodel in which parameters are fixed to zero or constrained to be equal is χ^2 distributed with the difference in the number of estimated parameters as the degrees of freedom. This χ^2 test was used to examine whether genetic and environmental contributions differed significantly from zero, whether there were sex differences in parameter estimates, and whether the relative importance of genetic and environmental effects differed at ages 3 and 7. To study sex differences, the analyses were performed on the five zygosity by sex twin groups (MZM, DZM, MZF, DZF, DOS). In all tests, a model that estimated all variance components in boys and girls separately was used as the baseline. Tests were performed for the persistent factors and age-specific factors separately. There were two exceptions. First, age-specific nonshared environmental effects are confounded with measurement error, so it does not make sense to test whether these effects are zero. Second, the test that equates the relative importance of genetic and environmental effects to be equal at ages 3 and 7 can be performed only for the age-specific effects. With three age-specific components for boys as well as for girls, this latter test implies six constraints. However, because the assessment instruments differ at ages 3 and 7 (e.g., the number of items), it is incorrect to assume equal phenotypic variances. To account for these scale differences, an additional parameter was estimated so that the total number of restrictions or degrees of freedom became 6 – 1 = 5.

The data were square-root transformed to approximate normal distributions that are required for maximum likelihood estimation. After transformation, all skewness and kurtosis indices were between –1.0 and 1.0, implying that not much distortion is to be expected in our test statistics (Muthén and Kaplan, 1985).

RESULTS

Table 1 shows the within-person correlations, the twin correlations, and the twin cross-correlations between ages 3 and 7 for boys and girls. We will first discuss the results that apply to the persistency of problem behaviors over time. The within-person correlations between ages 3 and 7 (stability coefficients) were on average lower for Internalizing Problems (boys, r = 0.35; girls, r = 0.41) than for Externalizing Problems (boys, r = 0.55; girls, r = 0.53). The twin cross-correlation between ages 3 and 7 were computed using the data from each twin pair twice (i.e., the average between the correlation of twin 1 assessed at age 3 with twin 2 assessed at age 7 and the correlation of twin 1 assessed at age 7 with twin 2 assessed at age 3). All twin cross-correlations between ages 3 and 7 were larger for MZ than for DZ twins, implying genetic contributions to stability. However, MZ cross-correlations were never twice as large as DZ cross-correlations, implying also shared environmental contributions to stability. In general the MZ twin cross-correlations were only slightly smaller than the within-person correlations between ages 3 and 7. This implied that nonshared environmental contributions to stability were small.

At each age, an overall estimate of genetic and environmental influences can be obtained by comparing MZ twin correlations with DZ twin correlations. At both ages and for both problem behaviors, MZ twin correlations were larger than DZ twin correlations, implying genetic influences. By subtracting the persistent genetic estimate discussed above (calculated using the twin cross-correlations) from this overall estimate of genetic variance at a certain age, one can determine the contributions of genes that are age-specific. In this study, age-specific genetic influences seemed to be important for both problem behaviors at both ages. The same technique can be used to estimate the age-specific shared and nonshared environmental influences. Age-specific shared environmental influences seemed to be more important than persistent factors for Internalizing

TABLE 1
Within-Person Correlations, Twin Correlations, and Twin Cross-Correlations Between Ages 3 and 7, for Internalizing and Externalizing Problems

	Within-Person Correlations (Stability Coefficients)				Twin Correlations and Twin Cross-Correlations Between Ages 3 and 7									
	Boys		Girls		MZ Boys		MZ Girls		DZ Boys		DZ Girls		Opposite Sex	
	3[a]	7	3	7	3	7	3	7	3	7	3	7	3	7
Internalizing Problems														
Age 3	1		1		.664		.739		.375		.346		.367	
Age 7	.345	1	.405	1	.233	.706	.418	.713	.213	.483	.226	.546	.214	.522
Externalizing Problems														
Age 3	1		1		.805		.826		.579		.533		.512	
Age 7	.552	1	.527	1	.487	.833	.536	.844	.357	.530	.299	.552	.302	.616

Note: MZ = monozygotic twins; DZ = dizygotic twins.
[a] Age (years).

Problems, while for Externalizing Problems the opposite seemed to be true. For the nonshared environmental factors, age-specific effects seemed to be more important than persistent effects for both problem behaviors at both ages.

The results from the tests for significance of genetic and environmental effects and sex differences are shown in Table 2. A large χ^2 and $p < .05$ implies that the constraints imposed by the model result in a significant deterioration in fit compared with the unconstrained model. The estimates for persistent and age-specific genetic, shared environmental, and nonshared environmental factors were all significant, implying that all variance components were larger than zero and necessary in the model. The sex differences were nonsignificant for persistent and significant for the age-specific effects. Thus the size of genetic and environmental effects for boys and girls was equal for the persistent factors but differed for the age-specific factors. Constraining the relative importance of genetic and environmental effects to be equal at ages 3 and 7 also resulted in a significantly poorer fit. In sum, the best-fitting model estimated the influences of all persistent and age-specific genetic, shared, and nonshared environmental factors; had no sex differences in genetic and environmental effects on persistent factors; and did have sex differences in genetic and environmental effects on age-specific factors. Furthermore, estimates at ages 3 and 7 had to be allowed to be different.

In Table 3 the total genetic and environmental contributions are reported for both sexes and age groups separately. These total influences are the sum of the part that was explained by persistent factors (first number within brackets) and the part that was accounted for by age-specific factors (second number within brackets). On average the phenotypic stability of Internalizing Problems (boys, $r = 0.35$; girls, $r = 0.41$) was for 66% genetically based, for 23% accounted for by shared environmental factors, and for 11% explained by nonshared environmental effects. The phenotypic stability of Externalizing Problems (boys, $r = 0.55$; girls, $r = 0.53$) was for 55% explained by genetic factors, for 37% by shared environmental factors, and for 8% by nonshared environmental effects.

The relative importance of persistent versus age-specific effects for a given component can be quantified by computing the genetic and environmental correlation coefficients. This is achieved in the standard way by dividing the covariance or shared variance by the product of the standard deviations at each age. For Internalizing/Externalizing Problems the correlations were 0.505/0.567 for genetic influences, 0.468/0.664 for shared environmental influences, and 0.130/0.235 for nonshared environmental effects.

For Externalizing Problems the estimated influences of genetic, shared, and nonshared environmental factors remained relatively constant at ages 3 and 7. For boys, these factors explained 43%, 37%, and 20%, respectively, at age 3 and 53%, 30%, and 17% at age 7. For girls, the estimated influences were 59%, 23%, and 18% at age 3 and 50%, 34%, and 16% at age 7. For both boys and girls at both ages, about half of the

TABLE 2
Chi-Square Differences Tests for Significance and Equality of Genetic and Environmental Contributions to Persistent and Age-Specific Effects

	Internalizing			Externalizing		
	χ^2	*df*	*p*	χ^2	*df*	*p*
Genetic effects = 0						
Persistent	50.218	2	.000	105.450	2	.000
Age-specific	75.299	4	.000	97.975	4	.000
Shared environmental effects = 0						
Persistent	8.728	2	.013	43.115	2	.000
Age-specific	24.884	4	.000	20.885	4	.000
Nonshared environmental effects = 0						
Persistent	11.215	2	.004	35.565	2	.000
Sex differences						
Persistent	1.450	3	.484	2.531	3	.282
Age-specific	81.890	6	.000	18.114	6	.000
Genetic and environmental effects equal age 3 and 7						
Age-specific	30.259	5	.000	23.180	5	.000

TABLE 3
Standardized Estimates from the Best-Fitting Model

	Internalizing Problems			Externalizing Problems		
	Genetic	Shared	Nonshared	Genetic	Shared	Nonshared
Boys						
Age 3	54 (25 + 29)	13 (9 + 4)	33 (4 + 29)	43 (26 + 17)	37 (18 + 19)	20 (4 + 16)
Age 7	46 (24 + 22)	26 (8 + 18)	28 (4 + 24)	53 (33 + 20)	30 (23 + 7)	17 (5 + 12)
Girls						
Age 3	63 (25 + 38)	8 (8 + 0)	29 (4 + 25)	59 (24 + 35)	23 (17 + 6)	18 (4 + 4)
Age 7	34 (23 + 11)	35 (8 + 27)	31 (4 + 27)	50 (36 + 14)	34 (25 + 9)	16 (5 + 11)

Note: Total contribution is divided into a persistent (first number within brackets) and an age-specific part (second number within brackets).

genetic variances were stable over time and half were age-specific. Thus, apart from finding persistent genetic influences, we found that about half of the genetic variance on Externalizing Problems at both ages was age-specific. Shared environmental factors mostly showed persistent influences, contributing to the stability of Externalizing Problems. Nonshared environmental factors, on the other hand, mostly showed age-specific effects.

For Internalizing Problems genetic influences decreased while shared environmental influences increased with age. For boys, the genetic, shared, and nonshared environmental factors explained 54%, 13%, and 33%, respectively, at age 3 and 46%, 26%, and 28% at age 7. For girls, the factors explained 63%, 8%, and 29% at age 3 and 34%, 35%, and 31% at age 7. Again, both for boys and girls at both ages, half of the genetic influences were stable and half were age-specific. Influences of both the shared and nonshared environmental factors showed mostly age-specific effects.

DISCUSSION

Maternal ratings of behavior problems in a large sample of 3- and 7-year old twins were used to estimate genetic and environmental contributions to stability and change. Genetic factors accounted for 66% of the phenotypic stability (r = 0.38) of Internalizing Problems and for 55% of the phenotypic stability (r = 0.54) of Externalizing Problems. Thus genes were most important for continuity in problem behaviors. Shared environmental influences accounted for 23% and 37% of the phenotypic stability of Internalizing and Externalizing Problems, respectively. This shared environmental effect agrees with epidemiological studies showing that the persistence of family discord and disruption, lack of affection, and poor supervision are associated with chronic problems (Campbell, 1995). Nonshared environmental factors were largely age-specific, implying that these effects are of a transient nature and children tend to "recover" from them.

Although genetic effects were important for stability, nearly half of the genetic variance was age-specific. Genes, therefore, also accounted for change. An explanation could be the many developmental changes that children experience between ages 3 and 7. It is therefore plausible that partly different genes are important for adjustment problems in preschool versus school-age children.

Whereas shared environmental effects on Internalizing Problems were small at age 3, they accounted for a substantial proportion of the variance at age 7. Because multiple comparisons were made, this could be a simple type I error. Another possibility is that the CBCL/2–3 Internalizing scale taps somewhat different behaviors than their counterparts in the CBCL/4–18. In very young children the Internalizing scale could more strongly reflect temperamental factors, whereas in older children it might be more closely related to affective symptoms. For Externalizing Problems, which involve more readily observable overt behaviors, the scales have clearer counterparts for preschool versus school-age children (Koot et al., 1997), and thus we did not observe a similar age difference for this scale. However, the increase in shared environmental effects could also reflect true developmental changes in Internalizing Problems. Compared with preschoolers, school-age children face more demands and have a larger set of responsibilities. They are therefore more exposed to potential risk factors. Parker and Asher (1987) showed, for instance, that social rejection by peers, which may be more likely in school-age children, is associated with Internalizing Problems. It may also

be important to realize that the shared environment is not confined to the home; shared environment also reflects the wider community in which families are embedded (Harris, 1995). Thus the larger shared environmental effects could also reflect the developmental trend that socialization experiences outside the home become increasingly important as children grow older.

The age-specific nonshared environmental effects are confounded with measurement error. An explanation for our finding that they were larger for Internalizing Problems than for Externalizing Problems can be that the former may be more difficult to measure in young children. This would be consistent with other reports showing that parents may be relatively insensitive to affective problems in children (Angold et al., 1987). It could also explain the lower stability we found for Internalizing Problems.

Limitations

Rater bias is a tendency of an individual rater to overestimate or underestimate scores consistently compared to the mean of all raters (e.g., as a result of different normative standards). Because mothers rated both twins, this would make the twins more similar and result in an overestimate of the shared environmental effects. However, when we accounted for these rater effects by including paternal ratings in our previous studies at ages 3 (van der Valk et al., 2001) and 7 (van der Valk et al., 2003), the conclusions remained largely the same. Furthermore, to account for rater bias effects confounded in the shared environmental contribution to continuity in problem behaviors, one would need to make the strong assumption that rater tendencies are stable across a 4-year period.

It will not be possible to generalize conclusions from this study to psychiatric conditions if psychopathology is caused by environmental hazards or pathogenic alleles that are qualitatively distinct from those that cause variation in the normal range (Rutter et al., 1990). However, there is evidence linking quantitative variation in the normal range to abnormal behavior. First, several CBCL studies have reported correlations between behavior problem syndromes and *DSM* diagnoses (Eaves et al., 1993; Edelbrock and Costello, 1988; Ferdinand et al., 1999; Kasius et al., 1997). This convergence indicates that our CBCL analyses must be relevant for psychiatric conditions. Second, when latent class analyses are performed to distinguish subgroups of children and adolescents with normal or pathological behavior, results tend to suggest differences in degree rather than in kind (Hudziak et al., 1998; Neuman et al., 1999). Furthermore, by fitting item response models, van den Oord et al. (2003) found that the liability distributions for delinquent behavior and emotional problems show very little or no evidence of nonnormality. Such analyses seem to indicate that psychopathology in children may often be an extreme on the same continuum that describes variation in the normal range. Thus these studies provide additional support that our analyses in a nonclinical sample are relevant for psychiatric conditions.

The large genetic influences we found in the present study do not imply genetic determinism. Even if genetic factors account for all variation in problem behaviors, which is not the case, that would not rule out the possibility of effective treatment (Pike and Plomin, 1996). In addition, environmental factors not widely represented at present in the population could have a major impact on problem behaviors. Finally, twins could be different than singletons. However, by comparing twins and singletons, we have not found major phenotypic differences in problem behaviors (van den Oord et al., 1995; van der Valk et al., 1998b, 2003).

Clinical Implications

For both Internalizing and Externalizing Problems, genetic and shared environmental effects were most important for stability. Thus, especially children who have a genetic risk and continue to experience adverse shared environmental influences may show persistent problems. For these children a wait-and-see policy may be inappropriate and an active intervention would be required.

To identify children who are at high genetic or shared environmental risk, diagnoses should be made on an etiological instead of symptom level. One approach to making such diagnoses is by considering the pattern of problem behaviors. For instance, in an earlier paper we found that in 3-year-olds high scores on all problem syndromes were more likely to indicate a shared environmental risk, while clusters of problem behaviors including either the Aggressive or Anxious symptoms were most suggestive of a high genetic risk (van den Oord et al., 2000). Another approach is to consider specific risk factors when making the diagnosis. This argues for the use of Axis 5 when making

DSM-IV diagnoses. In addition, progress has been made in identifying possible genes underlying childhood disorders (Smalley et al., 1998; Waldman et al., 1998). After collecting biological material in a noninvasive way, such as scraping the inner cheek with a cotton swab to obtain mucosa cells, it would in principle be possible to screen children for high-risk alleles. This information would be useful to identify children who are at high genetic risk for long-term adjustment problems.

Knowledge of the actual genes and the biological pathways that are involved could eventually also be helpful for successful intervention. This could be via medication that targets the relevant biological systems. However, there could be other options. There is, for instance, evidence that early intensive behavioral intervention may produce long-lasting and significant gains for a subset of young children with autism (McEachin et al., 1993). Given that autism has a strong genetic components, these findings suggest that behavioral interventions could in principle also be useful for genetically based problems.

REFERENCES

Achenbach TM (1991), *Manual for the Child Behavior Checklist/4–18 and 1991 Profile*. Burlington: University of Vermont, Department of Psychiatry

Achenbach TM (1992), *Manual for the Child Behavior Checklist/2–3 and 1992 Profile*. Burlington: University of Vermont, Department of Psychiatry

Angold A, Weissman MM, John K et al. (1987), Parent and child reports of depressive symptoms in children at low and high risk of depression. *J Child Psychol Psychiatry* 28:901–915

Barth JM, Parke RD (1993), Parent-child relationship influences on children's transition to school. *Merrill-Palmer Q* 39:173–195

Boomsma DI, Orlebeke JF, Van Baal GCM (1992), The Dutch twin register: growth data on weight and height. *Behav Genet* 22:247–251

Campbell SB (1995), Behavior problems in preschool children: a review of recent research. *J Child Psychol Psychiatry* 36:113–149

Caspi A, Moffitt TE, Newman DL, Silva PA (1996), Behavioral observations at age 3 years predict adult psychiatric disorders: longitudinal evidence form a birth cohort. *Arch Gen Psychiatry* 53:1033–1039

De Groot A, Koot HM, Verhulst FC (1994), Cross-cultural generalizability of the Child Behavior Checklist cross-informant syndromes. *Psychol Assess* 6:225–230

Eaves LJ, Silberg JL, Hewitt JK et al. (1993), Analyzing twin resemblance in multisymptom data: genetic application of a latent class model for symptoms of conduct disorder in juvenile boys. *Behav Genet* 23:5–19

Edelbrock C, Costello AJ (1988), Convergence between statistically derived behavior problem syndromes and child psychiatric diagnoses. *J Abnorm Child Psychol* 16:219–231

Ferdinand RF, Stijnen T, Verhulst FC, Van der Reijden M (1999), Associations between behavioural and emotional problems in adolescence and maladjustment in young adulthood. *J Adolesc* 22:123–136

Harris JR (1995), Where is the child's environment? A group socialization theory of development. *Psychol Rev* 102:458–489

Hartman CA, Hox J, Auerbach J et al. (1999), Syndrome dimensions of the Child Behavior Checklist: a critical empirical evaluation. *J Child Psychol Psychiatry* 40:1095–1116

Hudziak JJ, Heath AC, Madden PF et al. (1998), Latent class and factor analysis of *DSM-IV* ADHD: a twin study of female adolescents. *J Am Acad Child Adolesc Psychiatry* 37:848–857

Kasius MC, Ferdinand RF, van den Berg H, Verhulst FC (1997), Associations between different diagnostic approaches for child and adolescent psychopathology. *J Child Psychol Psychiatry* 38:625–632

Koot HM (1995), Longitudinal studies of general population and community samples. In: *The Epidemiology of Child and Adolescent Psychopathology,* Verhulst FC, Koot HM, eds. London: Oxford University Press, pp 337–365

Koot HM, van den Oord EJCG, Verhulst FC, Boomsma DI (1997), Behavioural and emotional problems in young pre-schoolers: cross-cultural testing of the validity of the Child Behavior Checklist 2/3. *J Abnorm Child Psychol* 25:183–196

Ladd GW, Price JM (1987), Predicting children's social and school adjustment following the transition from preschool to kindergarten. *Child Dev* 58:1168–1189

McEachin JJ, Smith T, Lovaas OI (1993), Long-term outcome for children with autism who received early intensive behavioral treatment. *Am J Ment Retard* 97:359–372

Muthén B, Kaplan D (1985), A comparison of some methodologies for the factor analysis of nonnormal Likert variables. *Br J Math Stat Psychol* 38:171–189

Neale MC, Boker SM, Xie G, Maes HH (1999), *Mx: Statistical Modeling*. Richmond, VA: Department of Psychiatry, Virginia Commonwealth University (*http://www.vcu.edu/mx/*)

Neale MC, Cardon LR (1992), *Methodology for Genetic Studies of Twins and Families*. Dordrecht: Kluwer

Neuman RJ, Todd RD, Heath AC et al. (1999), Evaluation of ADHD typology in three contrasting samples: a latent class approach. *J Am Acad Child Adolesc Psychiatry* 38:25–33

O'Connor TG, Neiderhiser JM, Reiss D, Hetherington EM, Plomin R (1998), Genetic contributions to continuity, change, and co-occurrence of antisocial and depressive symptoms in adolescence. *J Child Psychol Psychiatry* 39:323–336

Parker JG, Asher SR (1987), Peer relations and later personal adjustment: are low-accepted children at risk? *Psychol Bull* 102:357–389

Peterson JL, Zill N (1986), Marital disruption, parent-child relationships, and behavior problems in children. *J Marriage Fam* 48:295–307

Pike A, Plomin R (1996), Importance of nonshared environmental factors for childhood and adolescent psychopathology. *J Am Acad Child Adolesc Psychiatry* 35:560–570

Plomin R, DeFries JC, McClearn GE (1990), *Behavioral Genetics: A Primer*. San Francisco: Freeman

Rietveld MJH, van der Valk JC, Bongers IL, Stroet TM, Slagboom PE, Boomsma DI (2000), Zygosity diagnosis in young twins by parental report. *Twin Res* 3:134–141

Rutter M, Macdonald H, Le Couteur A, Harrington R, Bolton P, Bailey A (1990), Genetic factors in child psychiatric disorders, II: empirical findings. *J Child Psychol Psychiatry* 31:39–83

Schmitz S, Fulker DW, Mrazek DA (1995), Problem behavior in early and middle childhood: an initial behavior genetic analysis. *J Child Psychol Psychiatry* 36:1443–1458

Smalley SL, Bailey JN, Palmer CG et al. (1998), Evidence that the dopamine D4 receptor is a susceptibility gene in attention deficit hyperactivity disorder. *Mol Psychiatry* 3:427–430

Van den Oord EJCG, Boomsma DI, Verhulst FC (2000), A study of genetic and environmental effects on the co-occurrence of problem behaviors in three-year-old twins. *J Abnorm Psychol* 109:360–372

Van den Oord EJCG, Koot HM, Boomsma DI, Verhulst FC, Orlebeke JF (1995), A twin-singleton comparison of problem behaviour in 2-3-year-olds. *J Child Psychol Psychiatry* 36:449–458

Van den Oord EJCG, Pickles AP, Waldman ID (2003), Normal variation and abnormality: an empirical study of the liability distributions underlying depression and delinquency. *J Child Psychol Psychiatry* 44:180–192

Van den Oord EJCG, Rowe DC (1997), Continuity and change in children's social maladjustment: a developmental behavior genetic study. *Dev Psychol* 33:319–332

Van der Valk JC, van den Oord EJCG, Verhulst FC, Boomsma DI (2001), Using parental ratings to study the etiology of 3-year-old twins' problem behaviors: different views or rater bias? *J Child Psychol Psychiatry* 42:921–931

Van der Valk JC, van den Oord EJCG, Verhulst FC, Boomsma DI (2003), Using shared and unique parental views to study the etiology of 7-year-old twins' Internalizing and Externalizing Problems. *Behav Genet* 33: 407–418

Van der Valk JC, Verhulst FC, Neale MC, Boomsma DI (1998a), Longitudinal genetic analysis of problem behaviors in biologically related and unrelated adoptees. *Behav Genet* 28:365–380

Van der Valk JC, Verhulst FC, Stroet TM, Boomsma DI (1998b), Quantitative genetic analysis of Internalising and Externalising Problems in a large sample of 3-year-old twins. *Twin Res* 1:25–33

Waldman ID, Rowe DC, Abramowitz A et al. (1998), Association and linkage of the dopamine transporter gene and attention deficit hyperactivity disorder in children: heterogeneity owing to diagnostic subtype and severity. *Am J Hum Genet* 63:1767–1776