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Nature, Nurture, and Perceptions of the Classroom Environment as They Relate to Teacher-Assessed Academic Achievement: A twin study of nine-year-olds

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Although prior research has examined children's perceptions of the classroom environment as related to academic achievement, genetically sensitive designs have not been employed. In the first study of its kind for the primary school classroom environment, data were collected for 3,020 pairs of nine-year-old identical and fraternal twin pairs in same and different classrooms on their perceptions in six domains: social integration, opportunity, adventure, general satisfaction, negative affect, and teachers. Data were also collected for teacher-assessed academic achievement (ACH). Modest genetic influence was found for children's perceptions of the classroom environment: an average of .33, .06, .25, .27, .19, and .20 of the variance, respectively. Non-shared environment played a more influential role, accounting for an average of .58, .78, .64, .60, .69, and .65 of the variance, respectively. Negative affect, adventure, social integration, and opportunity were significantly, albeit modestly, associated with ACH. Results suggest that perceptions of the classroom environment are driven primarily by child-specific experiences, and that such perceptions, although experientially important, are less important for ACH.

A large body of research has examined how children perceive the classroom environment in order to understand better how to make learning environments more effective (e.g., Byrne, Hattie, & Fraser, 1986; Church, Elliot, & Gable, 2001; Entwisle, Kozeki, & Tate, 1989; Fraser & Fisher, 1982, 1983; Griffith, 2002; Stone & Meekyung, 2005). As schooling is a key mechanism for both social and cognitive development, it is important to understand not only issues related to school quality,

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but also how children's perceptions of the daily experience of school are related to academic achievement levels and other long-term adjustment outcomes.

Research shows that children's perceptions of the classroom environment have been found to influence, among other outcomes, depression, social rejection, school problems, and level of academic attainment (Anderman, 2002). Moreover, positive pupil perceptions of the classroom environment have been found to relate to lower levels of affective self-handicapping beyond that attributable to academic efficacy (Dorman, Adams, & Ferguson, 2002). Associations between children's perceptions and outcomes may be even more pronounced at the extremes (Wright & Cowen, 1982). In short, the ways in which children perceive their surroundings in the classroom have been found to relate to a broad spectrum of academic and adjustment outcomes.

Perceptions are important because they are the filter through which an individual's reality is understood (Johnson, 1987). A person's perceptions shape attitudes about the environment as well as behaviours within it. Some factors found to influence perceptions include prior social experience and background, organisational socialisation, the way in which people believe they are perceived by others, and personality characteristics (Forgus & Melamed, 1976). As related to the classroom, children's perceptions are largely responsible for mediating how they feel about relationships with teachers and peers, whether the learning environment is stimulating, and whether the classroom is generally a positive place to be.

However despite their importance, there has been very little research into the extent to which perceptions of the classroom environment are mediated by nature and nurture. For example, only two previous studies have examined perceptions of the classroom environment using a genetically sensitive twin design. Results from one study suggested that nurture played a more important role than nature in mediating adult retrospective perceptions of the high school classroom using the Classroom Environment Scale (CES; Trickett & Moos, 1995; Vernon, Jang, Harris, & McCarthy, 1997). Shared environment played a modest role, and genetics had a negligible to modest influence – only three CES scales out of nine (task orientation, rule clarity, and innovation) showed any evidence of heritability (.32, .19, and .28, respectively; Vernon et al., 1997). The other twin study found moderate genetic influence for adolescents' reports of positive interactions with best friends and teachers (.31 and .37, respectively; Manke, McGuire, Reiss, Hetherington, & Plomin, 1995). Virtually no genetic influence was found for adolescents' reports of negative interactions with best friends or teachers.

No study has investigated the genetic and environmental etiology of perceptions using current data for children in primary school. Examining the relative influence of nature and nurture on such perceptions requires the use of child-specific measures of the environment that are distinct for each twin in a family. An estimate of genetic influence can be obtained by treating the classroom environment as a dependent measure in a twin analysis, and assessing the degree to which the classroom environment is perceived more similarly by identical than by fraternal twins.

Over the past two decades, research into the family environment has been revolutionised by embedding family research in genetically sensitive designs in order to examine relationships between family environments and children's genetic propensities. Two key findings have emerged from this research. Genetics exert an important influence on experience (Bergeman, Plomin, Pedersen, & McClearn, 1991; O'Connor, 2002; Plomin, 1994; Plomin & Bergeman, 1991), and non-shared environment — environmental influences that make children growing up in the same family more different — also play a central role (Dunn & Plomin, 1990; Plomin, Asbury, & Dunn, 2001; Plomin & Daniels, 1987).

The first study of this type examined adolescent twins' perceptions of their parents, and found that MZ (monozygotic or identical) twins perceive their parents' emotional warmth towards them much more similarly than do DZ (dizygotic or fraternal) twins (Rowe, 1983). Genetic influence has also been found on ratings of shared parent–child positive affect and responsiveness (Deater-Deckard & O'Connor, 2000), and in children's perceptions of parent positivity and negativity (Plomin, Reiss, Hetherington, & Howe, 1994). Similar genetic influence has been found using observational measures of the home environment (O'Connor, Hetherington, Reiss, & Plomin, 1995). A twin study using the Home Observations for Measurement of the Environment (HOME; Caldwell & Bradley, 1978) to measure a mother's response to her children found that genetics played an important role (Braungart, Plomin, DeFries, & Fulker, 1993), as did videotaped observations of mother–child interactions (Dunn & Plomin, 1986; Rende, Slomkowski, Stocker, Fulker, & Plomin, 1992).

The mechanism for nature's influence on such environmental measures may lie in the genetic association with behavioural characteristics that mediate interactions between the individual and the environment, such as cognitive ability, personality, and adjustment (Plomin, DeFries, McClearn, & McGuffin, 2001). The "nature of nurture" (Plomin & Bergeman, 1991) provides an explanation for how genetics influences not only measures of child outcomes, but also measures of the environment. The process by which this works is known as a genotype–environment (G–E) correlation, in which children's genetic propensities are correlated with their experiences (Plomin, 1994; Plomin, DeFries, & Loehlin, 1977).

An important issue stemming from the examination of children's perceptions of the classroom environment is how such perceptions are related to academic outcomes. The relationship between children's perceptions and achievement is particularly relevant given that achievement levels are a well-established barometer of long-term life outcomes such as higher education, career, and socio-economic status (Hauser, Sewell, & Alwin, 1976; Luster & McAdoo, 1996; Sewell, Hauser, & Wolf, 1980). Although achievement is clearly an important indicator of later life results, how is attainment related to children's perceptions of the classroom?

In spite of evidence linking pupils' perceptions to various adjustment outcomes (Anderman, 2002; Myers & Fouts, 1982; Wright & Cowen, 1982), prior research linking perceptions to achievement has produced varied results. For example, there is evidence that children's perceptions of school belonging are related to higher levels of academic achievement (Anderman, 2002) and lower drop-out rates (Finn & Rock, 1997). Moreover, it has been found that adolescents' perceptions of the general classroom environment as measured by the CES (Trickett & Moos, 1973) are associated with academic attainment (Byrne et al., 1986). Such associations can be even more prominent for unpopular pupils, or those with pre-existing adjustment problems (Wright & Cowen, 1982). However, other research has found little relationship between children's perceptions of the classroom environment and achievement (Ainley & Bourke, 1992).

The goal of the current study is to investigate the genetic and environmental etiology of children's perceptions of the classroom environment. The hypothesis that non-shared environment is primarily responsible for mediating children's perceptions of the classroom will be tested. In addition, it is predicted that shared environment and genetics are less important that non-shared environment, when children are together in the same classroom and when they are in different classrooms. Finally, the relationship between children's perceptions and teacher-assessed academic achievement will be examined. This will be accomplished using a large and representative sample of nine-year-old identical and fraternal twins.

Method

Participants

The sampling frame for our study is the Twins Early Development Study (TEDS), a longitudinal population-based study of twins born in England and Wales in 1994 and 1995 (Trouton, Spinath, & Plomin, 2002). After screening for infant mortality, all families identified by the UK Office for National Statistics (ONS) as having twins born during 1994 and 1995 were contacted to take part in TEDS when the twins were about one year old. Subsequently, each family was sent a letter explaining the project along with a return-addressed postcard of interest. Parents who responded were mailed a first-contact booklet explaining the TEDS project in greater detail and requesting background demographic information.

Of the 6,921 families who received consent forms when the twins were nine and completing their fourth year in primary school, 4,077 (58.9%) agreed to participate in this study. Of the 4,076 child questionnaires sent, 3,358 (82.4%) responded for both twins. This produced a sample of 3,020 twin pairs for whom we had complete information. Despite attrition, it has been shown that the TEDS sample continues to be reasonably representative, in terms of education, parental ethnicity, and employment status, of the UK population of parents of young children (Spinath, Ronald, Harlaar, Price, & Plomin, 2003).

Physical similarity ratings by parents were used to determine the zygosity of the twins. This method was more than 95% accurate when validated with a sample of same-sex pairs using DNA markers (Price et al., 2000). Twins with complete data included 488 pairs of MZ males, 625 pairs of MZ females, 465 pairs of DZ males, 512 pairs of DZ females, and 930 pairs of DZ opposite-sex twins.

Measures

Classroom Environment Questionnaire. Children's perceptions of the classroom environment were assessed using a modified version of the School Life Questionnaire (SLQ; Ainley & Bourke, 1992), which we call the Classroom Environment Questionnaire (CEQ) in the current study. Two pilot studies were conducted, both including 100 non-TEDS families with 10-year-old twin pairs (50 MZ pairs and 50 DZ same-sex pairs). Results from the first pilot study were used to refine the adapted measure and conduct a second pilot study to confirm the reliability and validity of the final measure (CEQ). Details on the adaptation of the SLQ, as well as reliability and validity data for both pilot studies and the CEQ, are available from the first author (see Walker, 2004).

The teachers scale relates to the pupil–teacher relationship, and includes items such as perceptions of teacher helpfulness, fairness, and willingness to listen. The social integration scale includes items about relationships with other pupils, such as popularity, acceptance, and whether the child gets along well with others. Opportunity relates to whether classroom work is helpful preparation for the future, and contains items related to secondary school and the general usefulness of classroom learning. The adventure scale relates to love of learning, and includes items such as whether learning is fun, exciting, and interesting. General satisfaction relates to the child's general happiness level in the classroom, containing items such as whether the classroom is a place where the pupil likes to be, has fun, and feels happy. The negative affect scale includes items that inquire whether the child feels unhappy, upset, lonely, or worried while in the classroom.

Teacher-assessed academic achievement. Teachers' academic achievement assessments were based on UK National Curriculum (NC) criteria for Key Stage 2 (QCA, 1999), adjusted for age at the time of assessment. The NC is the core academic curriculum developed by the Qualifications and Curriculum Authority (QCA) and the National Foundation for Educational Research. NC curriculum criteria are uniform assessment guidelines followed by all teachers within the UK school system. For Key Stage 2, the QCA provides teachers with NC curriculum material, end of key stage scholastic aptitude tests (SATs), and grading keys for three academic categories within mathematics (using and applying mathematics; numbers; shapes, space, and measures), English (speaking and listening; reading; writing), and science (scientific enquiry; life processes and living things; physical processes). These nine subjects within English, mathematics, and science provided the basis for our teacher-assessed academic achievement scores at nine years of age.

The child's teacher determines which rating level is appropriate given the child's classroom performance. For example, a student receives a rating of 2 in writing if the pupil's writing communicates meaning in both narrative and non-narrative forms, uses appropriate and interesting vocabulary, and shows some awareness of the reader; a rating of 3 indicates that a pupil's writing is often organised, imaginative, and clear, and the main features of different forms of writing are being used appropriately and starting to be adapted to different readers; and a rating of 4 is given if a pupil's writing in a range of forms is lively and thoughtful, and ideas are often sustained and developed in interesting ways and organised appropriately for the purpose and the reader (QCA, 2002). A student performing below level 2 would receive a 1, and a student performing above level 4 receives a 5. There is no scholastic aptitude test (SAT) at nine years of age, and children's academic achievement levels are based strictly on teachers' assessments. Final scores range between 1 and 5.

Principal components factor analysis for teacher-assessed achievement at nine (ACH) yielded a first principal component that accounted for 71% of the variance within the nine academic subjects, highly similar to teacher-assessed academic achievement at seven years of age, with all academic subjects loading highly on this factor (see Walker, Petrill, Spinath, & Plomin, 2004). This ACH factor, adjusted for age and sex, provided the basis for our analysis of teacher-assessed achievement at nine years.

Although the validity of teacher assessments has been questioned (e.g., Davies & Brember, 1994; Demaray & Elliot, 1998; Glascoe, 2001; Reeves, Boyle, & Christie, 2001), a review of the literature has concluded that on the whole they are valid (Hoge & Coladarci, 1989). Moreover, Key Stage 1 teacher-assessed reading in the TEDS sample correlated .68 with a brief test of early word recognition (the Test of Early Word Reading Efficiency or TOWRE; Torgesen, Wagner, & Rashotte, 1999), which was administered via telephone to 5,808 seven-year-olds, providing additional support for the validity of teacher assessments (Dale, Harlaar, & Plomin, 2003). Finally, a comparison between Key Stage 1 NC teacher-assessed mathematics and NC objective mathematics tests for almost 600,000 pupils yielded a Cohen's (1960) kappa of .73, suggesting strong agreement between the two measures (Oliver et al., 2004).

Analyses

Phenotypic analyses. Means and standard deviations for gender and zygosity groups were calculated for the six CEQ scales and teacher-assessed academic achievement at age nine (ACH) to assess mean differences in gender and zygosity. CEQ means and standard deviations were also calculated separately for the highest and lowest 15% of ACH factor scores in order to examine differences in CEQ scores at the high and low achievement extremes.

Univariate genetic analyses. Twin analyses were conducted for the six CEQ scales, which makes use of the natural experiment provided by MZ and DZ twins (Plomin et al., 2001). MZ twins share all of their genes but DZ twins are only 50% similar genetically, as are siblings. For this reason, if genetic differences affect a particular trait, MZ twins will be more similar on that trait than will DZ twins. If MZ twins are no more similar than DZ twins, strong evidence is provided that genetics are not important for the trait. Moreover, the additional resemblance of MZ twin pairs relative to DZ pairs estimates half the genetic influence on the variance of the outcome measure. Doubling the difference in MZ and DZ twin correlations provides a rough estimate of "heritability", or the proportion of the observed (phenotypic) variance that can be attributed to genetic variance. The remaining within-pair similarity is accounted for by the shared environment, defined as environmental influences that make twins similar. Remaining variance not due to genes or shared environment is referred to as non-shared environment, defined as environmental influences that make twins in the same family different. Non-shared environment also includes measurement error. There also remains the issue of G–E correlation, in which the effects of genes are mediated via the environment. To the extent that such G–E correlations increase the resemblance of MZ twins more than DZ twins, these effects will be included in estimates of heritability (effect size of genetic influence) based on the twin design (Plomin et al., 2001).

The main concern with the twin method is the so-called equal environments assumption – the assumption that environmental similarity for MZ and DZ twins reared in the same family is similar (see review in Plomin et al., 2001). Violations of this assumption could inflate estimates of genetic influence. However, the equal environments assumption is supported by several studies (e.g., Bouchard & Propping, 1993; Kendler, Neale, Kessler, Heath, & Eaves, 1993; Loehlin & Nichols, 1976; Morris-Yates, Andrews, Howie, & Henderson, 1990). Further details on the strengths and weaknesses of the twin method are available elsewhere (Boomsma, Busjahn, & Peltonen, 2002; Bouchard & Propping, 1993; Martin, Boomsma, & Machin, 1997; Plomin et al., 2001).

Twin analyses. For twin analyses, correlations for the six CEQ scores were calculated for MZ and DZ twin pairs using standardised residual scores that adjust for sex differences. In addition to presenting MZ and DZ twin correlations as an indication of genetic and environmental influence, standard maximum-likelihood model-fitting was applied to the twin variance-covariance matrices using the structural-equation modelling package Mx (Neale, Boker, Xie, & Maes, 1999). Univariate models were fit to the observed data using gender-corrected scores as described above. Figure 1 shows the basic twin model.

Resemblance in a measured trait for twins reared together can be due to additive genetic factors (A) or shared or common environment (C). The path coefficients of latent variables A (genetic), C (shared environmental), and E (non-shared environmental, which includes error of measurement) factors are represented in Figure 1 by the lower case letters a, c, and e, respectively. Genetic relatedness is 1.0 for MZ twins and .5 for DZ twins. Shared environmental relatedness is assumed to be 1.0 for both MZ and DZ twins growing up in the same family. The latent E variable represents non-shared environmental influence, which contributes to differences between twins and also contains measurement error. The full ACE model dissects the phenotypic variance into these three components of variance (for details, see Plomin et al., 2001).

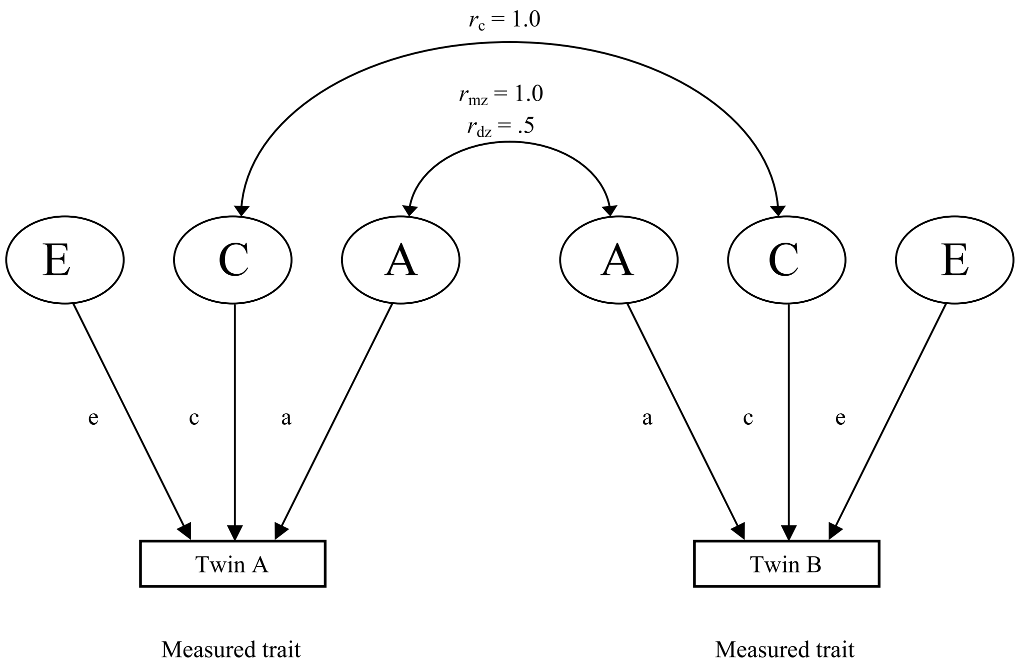

Figure 1. The standard twin model (Twin A and Twin B = twins in a pair, A = additive genetic influence, C = shared environment, E = non-shared environment, paths a, c, and e = effects of A, C, and E on a trait, r_c = shared environment correlation, r_{mz} = MZ correlation, r_{dz} = DZ correlation)

In order to take possible gender differences into account in the ACE model, a sex-limitation model was used that is based on data from five zygosity groups: MZ male pairs (MZM), MZ female pairs (MZF), DZ male pairs (DZM), DZ female pairs (DZF), and DZ opposite-sex pairs (DZO; Galsworthy, Dionne, Dale, & Plomin, 2000). By comparing all five zygosity groups, A, C, and E can be estimated separately for males and females (quantitative differences). The model further tests whether the genetic correlation between the sexes or the shared environmental correlation between DZO twins is less than for DZ same-sex twins, implicating the existence of factors that contribute to individual differences in one sex but not the other (qualitative differences). Moreover, the model allows for an assessment of separate and combined parameter estimates for males and females, as well as separate and combined parameter estimates for children in the same and in different classrooms.

A series of "nested" models can be tested and their fit can be compared by means of χ^2difference tests. In the present study, six models were compared: (1) a general or full sex-limitation model allowing quantitative and qualitative differences between males and females and estimating either the shared environmental correlation (r_C) or the genetic correlation (r_G); (2) a common-effects sex-limitation model allowing for quantitative differences between the sexes but fixing r_G or r_C to 1.0; (3) a scalar effects sex-limitation model which removes quantitative differences between males and females while still taking into account differences in variance, and either splits or equates parameter estimates for children in the same and in different classrooms; and (4) a null model which constrains all the parameters to be equal for males and females, as well as for children in the same and in different classrooms.

The above parameters and their 95% confidence intervals were estimated by fitting these models to variance/covariance matrices using Mx (Neale et al., 1999). Three fit indices are reported: the χ^2 statistic, Akaike's information criterion (AIC = $\chi^2 - 2df$; Akaike, 1987), and the root mean square error of approximation (RMSEA), which is the most appropriate fit statistic for large sample sizes.

Results

Phenotypic Analyses

Means and standard deviations for the six CEQ scales are shown separately in Table 1 by sex and zygosity. Significant gender differences were found for teachers ($F = 66.46$, $p < .01$), opportunity ($F = 45.25$, $p < .01$), adventure ($F = 87.25$, $p < .01$), general satisfaction ($F = 123.36$, $p < .01$), and social integration ($F = 7.11$, $p = .01$). Additionally, a significant interaction between gender and zygosity was found for negative affect ($F = 3.51$, $p = .03$). However, effect sizes were small (R^2 = .011, .008, .016, .019, .002, and .001, respectively). Significant mean gender and zygosity differences were found for teacher-assessed academic achievement ($F= 4.21$, $p = .04$; $F= 8.19$, $p < .01$, respectively), but the differences accounted for less than 1% of the variance.

Twin Correlations

Table 2 lists MZ and DZ intraclass correlations for the six scales of the CEQ (teachers, social integration, opportunity, adventure, general satisfaction, and negative

Table 1. Means and standard deviations for the Classroom Environment Questionnaire by gender and zygosity

		Teachers		Social integration		Opportunity		Adventure		General satisfaction		Negative affect	
	n	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
MZM	1026	1.52	.45	1.49	.47	1.69	.37	1.07	.56	1.47	.47	.29	.43
MZF	977	1.63	.45	1.50	.44	1.76	.33	1.25	.53	1.55	.44	.29	.44
DZM	1294	1.53	.48	1.44	.47	1.70	.36	1.09	.54	1.41	.49	.30	.44
DZF	1079	1.61	.46	1.49	.45	1.74	.33	1.17	.54	1.54	.45	.30	.44
DZO	1974	1.59	.45	1.48	.44	1.74	.34	1.16	.54	1.47	.46	.27	.42

Table 2. Twin correlations for the Classroom Environment Questionnaire for twins in the same classroom (S) and different classrooms (D)

		MZ	CI	*n*	DZS	CI	*n*	DZO	CI	*n*
Teachers	(S)	.47	(.43–.51)	663	.33	(.28–.38)	576	.37	(.32–.42)	544
	(D)	.25	(.19–.31)	454	.23	(.17–.30)	405	.06	(–.01–.13)	388
Social integration	(S)	.43	(.38–.47)	659	.26	(.20–.31)	574	.34	(.29–.39)	541
	(D)	.41	(.35–.46)	453	.22	(.15–.29)	400	.17	(.05–.19)	388
Opportunity	(S)	.25	(.20–.30)	663	.20	(.14–.25)	577	.23	(.17–.28)	542
	(D)	.19	(.19–.35)	455	.03	(–.01–.10)	405	.12	(.01–.19)	386
Adventure	(S)	.49	(.45–.53)	663	.31	(.26–.36)	574	.26	(.20–.31)	543
	(D)	.34	(.28–.40)	449	.23	(.16–.29)	401	.14	(.07–.21)	386
General satisfaction	(S)	.46	(.44–.51)	664	.31	(.26–.36)	575	.26	(.20–.31)	541
	(D)	.34	(.31–.43)	453	.21	(.14–.28)	403	.08	(.01–.15)	389
Negative affect	(S)	.26	(.21–.31)	656	.25	(.19–.30)	574	.14	(.08–.20)	538
	(D)	.37	(.31–.43)	451	.21	(.15–.28)	400	.24	(.17–.30)	385

Note. *n* denotes the number of twin pairs.

affect). For five of the CEQ scales, MZ correlations exceeded those of the DZS and DZO groups, suggesting that children's perceptions of the classroom environment are influenced by genetics. For opportunity, the twin correlations were similar for MZ and DZ twins, suggesting little genetic influence. Twin correlations tend to be lower when the twins are in different classrooms, which is to be expected because the twins are assessed in distinct physical environments. However, the average difference between MZ and DZ correlations, which is the essence of the estimate of genetic influence, is similar for children in different classrooms and those in the same classrooms (.12 and .16, respectively). Because MZ twins correlate only moderately, even when they are in the same classroom, non-shared environment appears important. Because DZ correlations are slightly greater than half the MZ correlations, some modest role for shared environment is suggested. Finally, because correlations are similar for same-sex and opposite-sex DZ twins, no qualitative sex differences are indicated.

Univariate Model-Fitting Analyses

As expected from the twin correlations in Table 2, model-fitting results suggested that for five of the six CEQ scales non-shared environment was substantial, heritability was modest, and shared environment was the smallest component of variance (see Figure 2). Results for the opportunity scale showed that the bulk of the variance was accounted for by non-shared environment, although shared environmental influence was modest, and genetic influence was virtually nil.

Detailed Mx results are shown in Table 3. For three of the six scales (social integration, negative affect, and opportunity), the null model provided the most

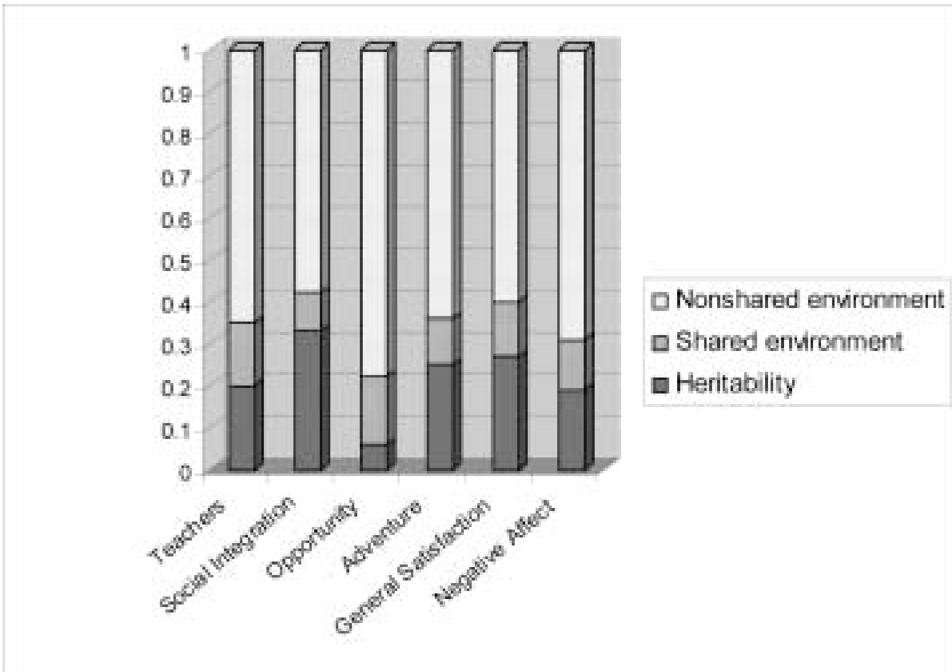

Figure 2. Average genetic and environmental parameter estimates for the six scales of the Classroom Environment Questionnaire (S denotes same classroom, D denotes different classrooms)

parsimonious fit with the data, indicating that parameter estimates could be equated for boys and girls, as well as for children in the same and in different classrooms. For social integration and negative affect, model-fitting results implied that genetic influence was moderate, shared environment influence was minimal, and non-shared environment influence was substantial whether children were in the same or in different classrooms. As expected from the twin correlations, model-fitting results for the opportunity scale indicated that shared environment influence was small, genetic influence even less, and non-shared environmental influence was substantial.

The scalar sex differences model fit the data best for teachers and adventure, suggesting again that parameter estimates could be equated for boys and girls although their variances differed; in addition, these models showed that parameter estimates differed for children in the same and in different classrooms. For the teachers scale, the difference was due to greater shared (and less non-shared) environmental influence for children in the same classroom as compared to different classrooms. However, for the adventure scale, the difference was due to greater genetic influence (and less non-shared environmental influence) for children in the same classroom.

For the general satisfaction scale, quantitative sex differences emerged as well as qualitative differences for children in the same and in different classrooms. Males

Table 3. Mx model-fitting results for six scales of the Classroom Environment Questionnaire

		χ^2	*df*	*p*	AIC	RMSEA	A	95% CI	C	95% CI	E	95% CI
Teachers	(S)	28.47	24	.24	−19.53	.018	.22	.07–.36	.24	.13–.35	.54	.49–.60
	(D)						.18	.00–.33	.06	.00–.22	.76	.67–.85
Social integration	(S&D)	24.85	27	.58	−29.15	.007	.33	.21–.46	.09	.00–.18	.58	.53–.63
Opportunity	(S&D)	24.83	26	.53	−27.17	.005	.06	.00–.20	.16	.06–.23	.78	.73–.83
Adventure	(S)	25.81	24	.36	−22.19	.004	.37	.22–.52	.10	.00–.22	.53	.48–.58
	(D)						.13	.00–.33	.12	.00–.25	.75	.67–.83
General satisfaction	(M–S)	27.16	16	.04	−4.55	.012	.44	.24 –.55	.06	.00–.22	.50	.43–.58
	(M–D)						.11	.00–.35	.30	.08–.43	.59	.52–.67
	(F–S)						.21	.00–.42	.13	.00–.34	.66	.56–.79
	(F–D)						.34	.04–.45	.02	.00–.26	.64	.55–.76
Negative affect	(S&D)	36.22	26	.09	−15.78	.011	.19	.05–.32	.12	.19–.22	.69	.64–.75

Note. S = results for same classroom; D = results for different classrooms; M = results for males; F = results for females.

showed higher heritability than females when in the same classroom, whereas genetics played a larger role for females when in different classrooms. Despite these differences, it is important to note that the confidence intervals overlapped substantially, an issue which will be addressed in the "Discussion" section below. When averaging the four parameter estimates, results for the general satisfaction scale were similar to the other CEQ scales in that non-shared environment accounted for the majority of the variance, heritability was relatively modest, and shared environmental influence was small (average .60, .27, and .13, respectively).

The Relationship between CEQ and ACH

Our goal was to conduct multivariate genetic analyses of the relationship between the CEQ and ACH. However, the six CEQ scales were too weakly correlated with ACH to permit multivariate genetic analyses that decompose phenotypic covariance into genetic and environmental components of covariance. Correlations between ACH and social integration, opportunity, adventure, and negative affect were significant but low (.01, .05, .08, and −.21, respectively). Correlations between ACH and teachers, as well as ACH and general satisfaction, were not significant. These findings are addressed in greater detail in the "Discussion" section.

In order to investigate whether the association between the CEQ and ACH was any stronger at the extremes of ACH, CEQ means were compared for the highest and lowest 15% of ACH (see Table 4.) These results confirmed the modest correlation between CEQ and ACH for the total sample. The largest CEQ difference occurred for negative affect, for which the effect size (*d*, the ratio of the mean difference to the pooled *SD*) was .61, accounting for about 8% of the variance in achievement scores. Other differences emerged for social integration and adventure, but these mean differences accounted for less than 1% of the variance for each scale.

Table 4. Classroom Environment Questionnaire mean scores for low and high 15% of academic achievement

	Low		High		All	
	M	*SD*	*M*	*SD*	*M*	*SD*
Student–teacher relationship scale	1.61	.45	1.57	.44	1.58	.46
Social integration scale	1.45	.46	1.52	.44	1.48	.45
Opportunity scale	1.70	.38	1.74	.34	1.73	.35
Adventure scale	1.13	.53	1.21	.54	1.16	.55
General satisfaction scale	1.49	.45	1.47	.47	1.48	.47
Negative affect scale	.44	.51	.18	.33	.28	.43

Note. Low extreme n = 485–492; high extreme n = 657–663; total n = 6515–6544; n denotes number of individuals.

Discussion

The current study investigated the relative influence of nature and nurture on children's perceptions of the classroom environment, and tested the relationship between those perceptions and teacher-assessed academic achievement at nine years old. Results suggest that whether children are in the same or in different classrooms, genetics play at least a modest role in mediating their perceptions. Shared environment contributed little; non-shared environment explained the majority of the variance. The most striking finding, in addition to the finding that shared environment contributes negligibly to perceptions of classroom environment even for children in the same classroom, is that nine-year-olds' perceptions have little to no relationship with teacher-assessed achievement. The only exception is negative affect, which shows a modest association with achievement.

Results from the current study provide support for earlier research suggesting that genes influence adolescents' perceptions of the classroom environment, but that non-shared environment plays the most substantial role (Manke et al., 1995; Vernon et al., 1997). In comparison with the study most similar to the present one (Vernon et al., 1997), the current study found heritability for all CEQ scales (.06–.37) rather than just some and, as a result, average heritability for all scales combined was higher (average .22 versus .09 in the earlier study). One possible reason is that the measure used in the earlier study, the CES (Trickett & Moos, 1995), asked twins to respond retrospectively to "whichever teacher or class they could best recall" (p. 99). In addition, the small sample size (93 MZ pairs, 116 DZ pairs) and wide age range (16–45 years) of the earlier study (Vernon et al., 1997) makes the differences in results unsurprising.

Despite the relatively modest average heritability of children's perceptions of the classroom environment, results underscore the importance of genetics. Regardless of whether identical twins were in the same or in different classrooms, they consistently viewed their school surroundings more similarly than did fraternal twins. This could be partly attributable to genetically influenced dispositional characteristics that filter the way in which children view their unique realities. Another possible explanation is G-E correlation, which, as discussed previously, denotes experiences that are correlated with genetic propensities (see Plomin et al., 2001). Specifically, "active" and "evocative" G-E correlations may partly account for the greater degree of perceptual similarity between identical twins. Active G-E correlation occurs when children seek or create environments associated with their genetic propensities, and evocative G-E correlation occurs when children evoke reactions from their environment based on their genetic propensities. In essence, identical twins may actively construct more similar types of learning environment than do fraternal twins. Moreover, behavioural and physical similarities between MZ pairs may evoke more similar responses from teachers, peers, and the general environment than do DZ pairs who are less similar behaviourally and physically.

For example, personality, which is moderately heritable (e.g., Loehlin, 1992), contributes to an individual's perceptions (Forgus & Melamed, 1976). Extraverted and curious children are more likely to ask questions in class, making the teacher more likely to respond by actively engaging them in classroom discussions and listening to their comments. In turn, such children are more likely to respond on the CEQ that the teacher "listens" and "takes an interest" in helping them learn. In other words, pupil–teacher chemistry is likely to be more similar for a pair of extraverted identical twins than for fraternal twins with distinct personalities.

Model-fitting results for three of the six CEQ scales (social integration, opportunity, and negative affect) showed that the difference in parameter estimates for children in the same and different classrooms was not statistically significant. However, results for the teachers and adventure scales showed that parameter estimates differed significantly when children were in the same versus different classrooms. This difference in results for the teachers scale make sense, as teacher–pupil chemistry is likely to vary widely depending on the unique characteristics of the teacher and the individual child. The adventure scale, which measures a child's love of learning, is also largely dependent on the child's relationship with the teacher – as well as the teacher's skill in making the subject matter come alive. A teacher who inspires the pupil to learn and makes learning fun is more apt to evoke CEQ responses from the child such as "my classwork is interesting," and "I get excited about the work we do."

Results for the general satisfaction scale yielded different parameter estimates for boys and girls, as well as for children in the same and in different classrooms. Similarly to the teachers and adventure scales, a teacher's skill in creating a vibrant and interesting learning environment plays an important role in determining whether children deem their classrooms to be places where they "like to be" and "feel happy". It is important to note that despite the differences in parameter estimates for teachers, adventure, and general satisfaction, overlapping confidence intervals suggest that the important focus should be on the general trend, which is that heritability for all CEQ scales is relatively modest and the contribution of non-shared environment is substantial. The opportunity scale, which measures the perceived usefulness of current schooling for the future, was the only domain that showed virtually no genetic influence (.06) – almost all of the variance was accounted for by non-shared environment (.78). This result suggests that despite potential similarity in messages sent by parents and teachers, a child's beliefs about the value of education are shaped in a highly individual manner.

Perhaps even more striking than the finding of modest genetic influence is the finding that shared environmental influence had negligible impact on children's perceptions of the classroom environment, although the twins were living in the same family and attending the same schools, and even when they were in the same classroom. These results parallel those of research into the home environment, which suggest that family environments tend to be experienced differently by children growing up in the same family (Plomin et al., 2001). Moreover, results from both the school and home environment are particularly interesting in light of earlier socialisation research, which assumed that shared environments enhanced similarities between children. The present findings underscore the individual nature of experience, and point to the necessity of research that more closely examines non-shared environment in the classroom. Such research would entail collecting detailed child-specific data in order to pinpoint how children's unique experiences of the school and classroom environment relate to educationally relevant behavioural outcomes.

Another major finding, albeit a negative one, is that perceptions of classroom environments are largely independent of teacher-assessed academic achievement. Although there is little extant research into children's perceptions of the elementary school classroom environment relative to achievement, the current finding is interesting in light of one prior study showing that school, classroom, and expressive support are positively related to elementary school children's self-reported grade point averages (Griffith, 2002). Other studies have found positive links between older students' perceptions of the classroom environment and achievement. For example, high school students' achievement scores are generally higher in classrooms perceived to be happy places with many opportunities (Byrne et al., 1986). Another study found that adolescents' perceptions of school climates correlate positively with achievement (Stone & Meekyung, 2005). A third study found that college students' perceptions of the classroom environment indirectly influenced academic performance via achievement goal adoption and intrinsic motivation (Church et al., 2001).

In the present study, only one of the six CEQ scales, negative affect, was importantly linked with achievement ($r = -.21$). The inverse relationship (more negative affect is associated with less achievement) is not surprising; research has shown that children's self-reports of depressed mood predict poor academic functioning (Ialongo, Edelsohn, & Kellam, 2002). Social integration, opportunity, and adventure also had significant relationships with achievement; however, correlations were low (.09, .05, and .08, respectively). Teachers and, most surprisingly, general satisfaction yielded non-significant correlations with achievement. The low to non-existent correlations were unexpected, as it is intuitive to think of these domains as being intimately interwoven, albeit in different ways, with academic success. This was clearly not the case in the current study. Although the explanation is not evident, perhaps the relationship between perceptions, attitudes about education, and teacher assessments become more pronounced later in children's school life. For example, it is possible that children's attitudes about the importance of present schooling for later schooling are as yet unformed, and that enjoying learning is more indicative of a general affinity for the process of exploration and discovery rather than incentive to master English, maths, and science. Moreover, relationships with teachers and peers, although important for a child's sense of connection to their classroom community, may be purely social (rather than academically motivating) and better reflected in measures of self-esteem rather than of scholastic success.

In order to examine more closely the relationship between children's perceptions of the classroom environment and achievement, the highest and lowest 15% of the teacher assessment factor scores were examined to see whether perceptions make a greater difference at the extremes of achievement. The pattern of results was highly similar to those for the entire sample. Again, negative affect was the only CEQ scale that showed a significant and substantial relationship with achievement.

The picture painted by the present results suggests that the beliefs children hold about their day-to-day lives in the classroom are complex and do not stem from a single source. This dynamic may emerge from the myriad areas of potential satisfaction in school such as creative endeavours, athletics, the learning process in and of itself, or simply being in a positive environment with friends. Alternatively, the CEQ may not be as effective in isolating perceptual dimensions associated with achievement as other measures such as the CES (Trickett & Moos, 1973). Either way, the current results validate prior findings that achievement levels and perceptions of the classroom environment in elementary school are relatively unrelated (Ainley & Bourke, 1992), suggesting that a child does not have to be an outstanding student in order to have a positive experience in school.

An exploration of mean gender and zygosity differences on the CEQ yielded few significant results. Although there were no zygosity-related differences for any scale other than negative affect (which accounted for 1% of the variance), an analysis of gender-based means suggested that females generally held a more positive view of most aspects of the classroom environment than males. This is consistent with other studies of school life (Ainley & Bourke, 1992; Ainley, Reed, & Miller, 1986; Epstein, 1981). Specifically, female mean scores were higher than those of males for teachers, general satisfaction, opportunity, social integration, and adventure. However the differences accounted for less than 2% of the variance for each measure. Gender differences in the current study were highly similar to those for the published measure (Ainley & Bourke, 1992).

It is true that self-report data from 10-year-olds can be prone to validity issues stemming from mood disturbance and withdrawal (Wrobel & Lachar, 1998). Nonetheless, despite potential concerns about the validity of self-report measures, it can be argued that children's perceptions are more valid than those of third-party observers, as children's perceptions are by definition their reality. It is specifically this perceived reality that is being examined by the CEQ in the current analyses.

As so little educationally relevant research considers the importance of both genetics and the environment (Plomin & Walker, 2003), studies of this nature are important to heighten awareness and provide insight to teachers about the dynamics underlying the behavioural characteristics of pupils in their classrooms. Results from the current study suggest that although genetics play an important role, non-shared environment has the strongest influence on children's perceptions of the classroom environment at nine years old. The finding that heritability remains even when children are in different classrooms and are experiencing entirely different environments provides evidence that children's experiences of the primary school classroom environment are at least partly mediated by genetics. However, the substantial contribution of non-shared environment suggests that, regardless of genetic similarity, an individual child's experience of the classroom is just that: individual.

Contributing factors to non-shared environment are aspects of experience that differentiate one child's reality from another's, such as the unique personal chemistry a particular child shares with teachers and peers, or situations that are internalised in a distinct way stemming from prior life events. The concept that environmental similarity does not necessarily cause resemblance in perceptions of day-to-day reality is reinforced by the negligible contribution of shared environment in the current study — despite children sharing the same home, school, and classroom. Finally, children's levels of academic achievement proved to be relatively independent of how they perceived the elementary school classroom environment — a surprising finding, but one that is in line with prior research. In short, these results suggest that the early educational experience is mediated somewhat by nature but primarily by nurture, that the classroom tends to differentiate children further rather than make them more similar, and that perceptions of the classroom environment have little effect on academic outcomes.

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