Clones in the Classroom: A Daily Diary Study of the Nonshared Environmental Relationship Between Monozygotic Twin Differences in School Experience and Achievement

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Do genetically identical children experience the same classroom differently? Are nonshared classroom experiences associated with differences in achievement? We designed a telephone diary measure which we administered every school day for 2 weeks to 122 10-year-olds in 61 monozygotic (MZ) twin pairs. Each pair shared genes, a classroom, peers and a teacher. We found that MZ twins did experience their classrooms differently (rMZ < 0.65 for all measures of classroom experience). Furthermore, MZ differences in peer problems were significantly associated with MZ differences in Mathematics achievement (ES = 8%); differences in positivity about school were significantly associated with differences in Mathematics (ES = 15%) and Science (ES = 8%) achievement; and differences in 'flow' in Science lessons were associated with differences in Science achievement (ES = 12%). In a multiple regression analysis, MZ differences in positivity about school significantly predicted MZ differences in Mathematics achievement (R^2 = 0.16, p < .01) and MZ differences in 'flow' in Science significantly predicted MZ differences in Science achievement (R^2 = 0.10, p < .05). These results indicate that MZ twins experience the classroom differently and that differences in their experience are associated with differences in their achievement.

Keywords: Nonshared environment, diary study, classroom environment, academic achievement, monozygotic twins

Maria Montessori argued that 'One test of the correctness of educational procedure is the happiness of the child'. Another must surely be the success of each child in achieving their full potential. Our study was designed to explore the influence of the classroom environment, and the child's happiness within it, on achievement in English, Mathematics and Science.

Behavioral genetic research has consistently indicated that academic achievement is moderately heritable and that nonshared environmental influence (NSE) can account for about 25% of the variability in children's achievement, although this includes error of measurement (Kovas et al., 2007). However, there has been little progress in identifying influential measurable NSE experiences. NSE represents a child's unique experiences or perceptions, the parts of life that are not shared by children growing up in the same family (Daniels & Plomin, 1985; Plomin et al., 2001; Turkheimer & Waldron, 2000). A recent study found that the classroom is experienced uniquely, even by monozygtic (MZ) twins who share all of their genes and much of their environment (Walker & Plomin, 2006). Further, NSE was found to be a stronger influence than either genes or shared environment on these 9-year-olds' perceptions of their classroom experience. The classroom therefore represents a strong potential source of NSE influence.

That there should be an association between a well-organized classroom, high quality teaching, good relationships, interesting and engaging lessons and academic achievement makes intuitive sense. To an extent, this intuition has been borne out by research. For example, Anderman (2002) found a significant link between school belonging and grade point averages (r = .21, p < .01), an effect size of 4%. Most research in this field, like the Anderman (2002) study, has been focused on children in high school (e.g. Griffith, 2002; Stone & Han, 2005; Wright & Cowen, 1982). With a small number of exceptions it has not controlled for

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the influence of genes on either classroom experience or academic achievement (the exceptions are Trickett & Moos, 1995; Vernon et al., 1997). Walker and Plomin (2006), in a genetically sensitive study, and in line with previous elementary school-based research (Ainley & Bourke, 1992), found almost no significant association between children's perceptions of the classroom environment and school achievement. These studies suggest that although classroom experience appears to be a genuinely nonshared environment, it does not influence achievement. However, other nongenetic studies have found significant associations between the elementary school environment and achievement (Hamre & Pianta, 2005). The evidence is, therefore, mixed.

We wanted to approach this relationship with a different study design and a new and richer measure of the classroom environment. We employed an MZ differences design as an efficient and proven way of getting at NSE (Asbury et al., 2003; Asbury et al., 2006, Caspi et al., 2004, Oliver et al., 2008). Any differences between MZ twins cannot be caused by genes, because MZ twins share their genes. Nor, by definition, can MZ differences be the result of shared environmental influence. They can only be accounted for by NSE, or by measurement error (Pike et al., 1996). By using an MZ differences design we could explore whether identical twins in the same classroom experience their classroom differently as found by Walker and Plomin (2006). The MZ differences design would also allow us to search directly for nonshared environmental associations between MZ differences in experience and MZ differences in achievement, independent of genetics and measurement error.

The few previous nonshared environment studies of classroom environment relied on questionnaires administered on a single measurement occasion. We considered it necessary to approach the problem of nonshared environment with a new and more in-depth measure of the classroom environment. Diary research has suggested that frequent, minor stressors may have a more damaging effect on health and wellbeing than major traumatic events (e.g., Lazarus, 1999; Zautra, 2003). Almeida (2005) quotes Chekhov as saying: 'Any idiot can handle a crisis — it's this day-to-day living that wears you out'. This raises the question of whether frequent minor stressors such as late homework, tests, falling out with friends and being told off by teachers may have a similar impact on child outcomes, a 'grinding down' effect. The diary method has been used successfully in studies with adolescent samples (Fuligni et al., 2002; Henker et al., 2002) but a diary study with younger children was a novel aspect of our study. A range of approaches from pencil-and-paper questionnaires through to telephone and electronic diaries have been employed. We decided to take the telephone diary approach with our middle-childhood sample. A telephone diary should have greater validity than a pencil-and-paper questionnaire as answers are given at a known time and cannot be altered later by respondents. Self-report data from this age group can be unreliable. Our 2-week telephone diary approach represents our attempt to ensure that data are as accurate and informative as possible by allowing children to report their experiences close to the time they occur (Stone et al., 2002; Wrobel & Lachar, 1998).

Amid increasing academic and media reports of the rise of stress in childhood in an age of vastly increased formal testing of children in many countries including the United Kingdom (Connor, 2003), it was deemed appropriate to conceptualize classroom experience as a series of potential stressors. Academic pressures, peer problems and poor teacher–child relationships are known correlates of a range of negative outcomes (Elias et al., 1992; Hamre & Pianta, 2005). Stress is also the usual focus of the diary method. However, we also wanted to explore positive classroom experiences as research has indicated that a sense of positivity about school can be associated with positive outcomes (e.g., Dorman et al., 2002). A further innovation was to adapt the psychological concept of 'flow' to assess the degree to which children were happily engaged in their lessons (Csikszentmihalyi & Csikszentmihalyi, 1988). Research has found engagement in lessons to be related to teacher and peer relationships (Patrick et al., 2007).

Mihalyi Csikszentmihalyi describes a person 'in flow' as being deeply involved in a 'flow' activity, be it playing the cello, washing the car, walking the Inca Trail or walking the dog. They will positively want to take part in the activity in question, will not be bored and will not have to make an effort to concentrate. Csikszentmihalyi's Flow Questionnaire is used to identify and measure how often people have 'flow' experiences. In its standard form it consists of three quotations from a rock climber, a composer and a dancer, each of whom were recorded describing their own experiences; for example, 'My mind isn't wandering. I am not thinking of something else. I am totally involved in what I am doing. My body feels good. I don't seem to hear anything. The world seems to be cut off from me. I am less aware of myself and my problems'. After reading the quotations respondents are asked if they have experienced similar feelings and what activities prompted them. Respondents who say they have never experienced anything like any of the three quotations receive a score of 0. A maximum score of 3 is given to respondents who can identify with all three quotations. Then, once a 'flow' activity is identified the respondent rates it according to a 12-dimension scale made up of items such as 'I get involved' and 'I get distracted'. Csikszentmihalyi and colleagues are interested in the relationship between 'flow' and trait happiness. We viewed 'flow' as an indicator of state happiness and were interested to explore the relationship between classroom 'flow' and academic achievement.

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Academic achievement matters. It is certainly not the only school outcome that matters, as Montessori and many others have pointed out, but it is nonetheless important. Children who do well in school have been found to experience significantly better lifelong prospects and outcomes than those who fail academically (e.g., Hauser et al., 1976; Luster & McAdoo, 1996). If subjective classroom experience has an impact on achievement, it is important to understand which aspects of the experience matter the most and how they make their impact. One study has suggested that high-quality classrooms, with excellent instructional and emotional support from teachers, can help to close the gap between first grade children at risk for school failure and those not at risk (Hamre & Pianta, 2005). This finding has important implications for educational interventions that may benefit the most needy children in society and help to close the oft-cited gulf between high and low achievers in some countries, including the United Kingdom.

Our aims in the current study were to design and administer a daily diary measure of child-specific classroom experience, and to explore whether identical twins in the same classroom have different perceptions of it. Should this be the case, we planned to test for associations between the classroom environment and achievement and, in particular, to test whether discordance in subjective classroom experience can predict discordance in objective academic achievement.

Method

Sample

MZ twin pairs were drawn from the 1994/1995 cohort of the Twin's Early Development Study (TEDS). TEDS is a longitudinal study of UK twins born between 1994 and 1996, and has been in contact with the children and their families since infancy. TEDS has been shown to be reasonably representative of the UK population and is described elsewhere (Oliver & Plomin, 2007; Trouton et al., 2002). All selected pairs were 10-years-old in Year 5, the penultimate year of elementary schooling in the United Kingdom. Both twins in each pair were pupils in the same classroom. We aimed to recruit 60 twin pairs so we identified 120 families with a representative SES distribution. We divided these families into 12 SES-based groups and allocated a group of 10 families to each of 12 telephone interviewers. Each caller was asked to recruit five twin pairs from their list and to stop calling when they had done so. In fact we recruited 61 MZ twin pairs. We were largely successful in recruiting a sample that is representative in terms of SES as the mean SES for our sample was 0.02, very close to the 0.00 mean for the full TEDS sample, although an excess of female pairs (N = 38) volunteered. All families provided informed consent and understood that they were free to withdraw from the study at any point. None chose to do so.

Procedure

We designed our diary measure of classroom experience and conducted a feasibility study with ten twin pairs. We used this feasibility study to refine the measure in terms of language, length and content, and to assess whether 2 weeks was a reasonable amount of time to expect participation from TEDS families. Interviews usually took between 5 and 10 minutes per day for each child and feedback suggested that neither the twins nor their parents considered this to be too long. We found that families did not object to either the regularity or the length of the commitment asked of them, making the approach a feasible one. The feasibility study also gave us a valuable opportunity for testing the online data entry system and telephone interview procedure we had established. When the measure and procedures were finalized, we conducted two interviewer training sessions with experienced TEDS telephone interviewers, and began to recruit families for the study. All interviews took place in the same two-week period every evening after school. Data were entered online during the interview. We used descriptive statistics, correlations and multiple regression analysis to address the research aims described in the introduction to this article.

Measures

We designed a measure of nonshared environmental stress and positivity in the school environment to be administered to 10-year-old children using a daily telephone diary approach. We generated some items ourselves but most were drawn from published sources. See Table 1.

Peer Stressors

Children were asked about six peer stressors each day using questions including: 'Did you argue with a pupil in your class today?', 'Did you have a physical fight

Table 1

Origins of Items in Environmental Measures

	Total number of items	Generated in-house	Fuligni et al., 2002	Weinstein & Marshall, 1984	Csikszentmihalyi & Csikszentmihalyi, 1988
Peer stressors	**6**	4	2	—	—
Academic stressors	**6**	2	4	—	—
Teacher–child interactions	**12**	2	—	10	—
'Flow'	**6**	—	—	—	6

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with a pupil in your class today?' and 'Were you excluded or left out of anything by someone today?' Two of these items were drawn from Fuligni et al. (2002) and four were generated in-house. Items were followed with this probe whenever an affirmative was given: 'Did this bother you a lot, a bit, not much or not at all?' These items form the basis for our 'total peer stressors' and 'upset caused by peer stressors' variables.

Academic Stressors

Academic stressors were also measured using six items, four of which were drawn from Fuligni et al. (2002), including: 'Did you have a test in school today?', 'Did you struggle to understand something in class today?' and 'Did you fail to hand in some homework that was due today?' Once again these items were followed with the same probe about how bothered the child was by each stressor they experienced.

Relationship With Teacher

Children were also asked about their relationship with their teacher using 12 items relating to both positive and negative experiences. Ten of the 12 items came from Weinstein & Marshall (1984). Positive items included: 'Did your teacher call on you to answer questions today?' and 'Did your teacher spend a lot of time working one-to-one with students today?' Negative items included: 'Did your teacher make you feel that you had not done your work well today?' and 'Did your teacher tell you off today for not listening in class?' Once again, the negative items were followed with a probe about how bothered the child was if they answered yes, and these data provided us with three variables for analysis: 'total teacher stressors', 'upset caused by teacher stressors' and 'positive teacher experiences'.

Flow and Positivity

Our measure of 'flow' was based on the second part of Csikszentmihalyi's 'flow' questionnaire (Csikszentmihalyi & Csikszentmihalyi, 1988). The first part of the original questionnaire focuses on identifying a 'flow' experience and the second on identifying an individual's degree of 'flow' while involved in such an experience. This is done using a 12-dimension scale made up of statements such as 'I get involved' and 'I get anxious'. Because we had already identified our 'flow' activity of interest, namely English, Mathematics and Science lessons, we assessed degree of flow using six of Csikszentmihalyi's 12 statements such as 'I knew exactly what I was meant to be doing' and 'I got bored'. Language was changed slightly where necessary to make items age appropriate and easily understood over the telephone. Children were asked whether each of these statements was very true, quite true, not very true or not at all true of how they felt in their English/Mathematics/Science lesson that day. We thus generated 'flow in English', 'flow in Mathematics' and 'flow in Science' variables.

Average Day Rating

Finally, we ended the interview each day by asking: 'What number between 1 and 10 best describes your day at school today, if 1 is the worst day you could possibly have and 10 is the best?'

Academic Achievement

We contacted the teachers of all 61 pairs of twins, with a request for National Curriculum ratings of each child's achievement level in English, Maths and Science. The National Curriculum (NC) is the UK's core academic curriculum developed by the Qualifications and Curriculum Authority (QCA: http://www.qca.org.uk). For NC teacher assessments teachers summarize each child's performance in three domains for each subject, using a 5-point-scale. We combined the three domains to make composite subject scores. 48 teachers responded, giving us academic achievement data for 48 twin pairs. Data were complete for Mathematics and Science achievement but we received complete data on English achievement, for both twins in the pair, in only 46 instances.

Results

Descriptive Statistics

Table 2 shows descriptive and reliability statistics for all measures used in the study. Daily measures were aggregated across each week and all of the data were standardized to zero mean and unit variance. Means and standard deviations are presented separately for boys and girls.

It can be seen that most differences between the sexes were nonsignificant, with the exceptions of 'flow' in English lessons, average day ratings and teacher-rated Mathematics achievement. Girls reported being significantly more in 'flow' during their English classes and were also significantly more positive about their school day. Previous studies have also found females to be more positive about school than males (Ainley & Bourke, 1992; Walker & Plomin, 2006). For the three academic achievement measures, the only significant difference was a higher mean for boys, which is comparable to our previously reported results (Kovas et al., 2007).

Test–Retest Reliabilities

Scores were derived separately for each of the 2 weeks' assessments. Table 2 lists correlations between Week 1 and Week 2, as well as test–retest reliabilities adjusted by the Spearman-Brown prediction formula as an index of reliability relevant to the 2-week scores upon which our analyses are based. The correlations between Week 1 and Week 2 (r_{1-2}) were corrected according to the Spearman-Brown formula: $(2 \times r_{1\text{-}2}) / (1 + r_{1-2})$.

Reliability for our measures of school experience was assessed using one twin per pair; highly similar results were obtained when the other twin of each pair was used. All of the correlations between Week 1 and Week 2 are significant and the reliability estimates vary from .48 to .77 for the six stressor measures, .74 for total positive teacher interactions, .74 to .90 for the three flow measures, and .84 for the

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Table 2

Descriptive and Reliability Statistics and MZ Twin Correlations for School Experience and Achievement Measures

	Girls' M (SD)	Boys' M (SD)	*p* of sex diff	Correlation between Week 1 and Week 2	Correlation between Week 1 and Week 2 corrected for unreliability[1]	MZ twin correlation
Total number of peer stressors	0.01 (1.14)	–0.02 (0.71)	0.84	0.43**	0.60	0.48**
Upset caused by peer stressors	0.05 (1.18)	–0.08 (0.58)	0.41	0.34**	0.51	0.48**
Total number of academic stressors	0.06 (1.06)	–0.10 (0.90)	0.40	0.46**	0.63	0.64**
Upset caused by academic stressors	0.04 (1.06)	–0.07 (0.90)	0.56	0.60**	0.75	0.43**
Total number of teacher stressors	–0.05 (0.93)	0.07 (1.11)	0.53	0.63**	0.77	0.16
Upset caused by teacher stressors	0.03 (1.12)	–0.04 (0.78)	0.70	0.32*	0.48	0.25*
Total positive teacher interactions	–0.05 (0.99)	0.08 (1.02)	0.48	0.59**	0.74	0.45**
Flow in English	0.14 (1.02)	–0.22 (0.93)	0.05*	0.80**	0.89	0.63**
Flow in Mathematics	0.10 (1.01)	–0.17 (0.97)	0.15	0.81**	0.90	0.61**
Flow in Science	0.09 (1.03)	–0.15 (0.94)	0.23	0.59**	0.74	0.36**
Average day rating	0.19 (0.95)	–0.32 (1.00)	0.01**	0.72**	0.84	0.55**
English achievement	–0.06 (0.93)	0.09 (1.11)	0.48			0.78**
Mathematics achievement	–0.20 (0.98)	0.34 (0.95)	0.01**			0.82**
Science achievement	–0.11 (0.94)	0.18 (1.08)	0.20			0.78**

Note: $N = 122$ children (76 girls and 46 boys) in 61 MZ twin pairs.

[1]The Spearman Brown correction uses the following formula: $(2 \times r_{1\text{-}2}) / (1 + r_{1\text{-}2})$ to correct for unreliability.

average day rating. Previous research has shown our measures of achievement to be reliable and valid (Kovas et al., 2007).

Nonshared Environment

Table 2 also shows MZ twin correlations (ICCs) for the 2-week measures. These MZ correlations vary from $r = .16$ to $r = .64$, suggesting that MZ twins in the same classroom perceive quite different classroom environments. More precisely, nonshared environment plus measurement error accounts for much of the variance of these measures of school experience, from 36% to 84%. For teacher-rated achievement in English, Maths and Science, MZ correlations were in tune with what we would expect from previous research and all showed room for nonshared influence to the extent that they were less than $r = 1.00$ ($r = .78$ for English; $r = .82$ for Mathematics and $r = .78$ for Science.

Correlations Between Measures of School Experience

Table 3 shows intercorrelations between all diary variables based on total, rather than weekly or daily scores. The lower diagonal shows phenotypic correlations, based on one twin per pair. The upper diagonal shows nonshared environmental (MZ differences) correlations.

Phenotypic Correlations Between Diary Measures

The degree of peer, academic or teacher-related stress experienced correlates highly with how upset children were about that particular type of stress ($r = .93$, $p < .01$ for peer stressors; $r = .84$, $p < .01$ for academic stressors; and $r = .90$, $p < .01$ for teacher stressors). Correlations between the three different kinds of stressor, and also reactivity to the stressors, were generally low to moderate. The highest was between peer and teacher stressors ($r = .54$, $p < .01$) suggesting that children who felt they experienced problems with peers also felt they experienced problems with teachers. This is perhaps indicative of a more general vulnerability to 'social stressors'.

Peer stressors and reactions to them were significantly negatively associated with 'flow' in English and Mathematics and with positivity about the school day. In fact, all stressors (and stress reactions) were associated negatively with 'flow' and positivity and in 14/24 instances the correlations were significant. Stress appeared to interfere with children's 'flow', and with their happiness at school.

Nonshared Environmental Correlations Between Diary Measures

Looking at the upper diagonal of Table 3 we see nonshared relationships between our diary variables, that is, correlations between MZ differences in each aspect of experience measured. As with the phenotypic correlations, MZ differences in the number of stressors experienced correlated highly with MZ differences in upset caused by the relevant stressor ($r = .91$, $p < .01$ for peers; $r = .79$, $p < .01$ for academic pressures; and $r = .85$, $p < .01$ for teacher stressors). Once again, correlations between MZ differences in all three kinds of stressor, and the distress caused by them, were low to moderate.

MZ differences in exposure to peer stressors correlated significantly with MZ differences in 'flow' in English ($r = –.36$, $p < .01$) with the twin experiencing more peer stressors, and feeling more upset by them

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Table 3

Intercorrelations Between Diary Measures

	PS	Upset PS	AS	Upset AS	TS	Upset TS	PT	English flow	Maths flow	Science flow	ADR
Total number of peer stressors (PS)	**1.00**	0.91**	0.28*	0.26*	0.38**	0.38**	0.20	–0.36**	–0.12	–0.11	–0.11
Upset caused by peer stressors (Upset PS)	0.93**	**1.00**	0.20	0.24	0.31*	0.36**	0.22	–0.37**	–0.17	–0.15	–0.26
Total number of academic stressors (AS)	0.29*	0.36**	**1.00**	0.79**	0.12	0.26*	0.33**	–0.14	–0.09	–0.21	–0.21
Upset caused by academic stressors (Upset AS)	0.32*	0.38**	0.84**	**1.00**	0.18	0.44**	0.21	–0.27*	–0.15	–0.30*	–0.30*
Total number of teacher stressors (TS)	0.54**	0.47**	0.39**	0.38**	**1.00**	0.85**	–0.10	–0.18	–0.09	0.04	–0.03
Upset caused by teacher stressors (Upset TS)	0.59**	0.47**	0.33*	0.35**	0.90**	**1.00**	–0.10	–0.21	–0.11	–0.03	–0.13
Total positive teacher interactions (PT)	0.16	0.07	0.35**	0.23	0.26	0.14	**1.00**	–0.05	–0.07	–0.06	0.01
Flow in English	–0.47**	–0.44**	–0.24	–0.35**	–0.20	–0.30*	–0.09	**1.00**	0.31*	0.37**	0.49**
Flow in Mathematics	–0.43**	–0.42**	–0.26*	–0.46**	–0.11	–0.26*	–0.04	0.88**	**1.00**	0.82**	0.60**
Flow in Science	–0.25	–0.25	–0.37**	–0.56**	–0.14	–0.23	–0.04	0.67**	0.73**	**1.00**	0.65**
Average day rating (ADR)	–0.37**	–0.34**	–0.10	–0.23	–0.25	–0.45**	–0.05	0.57**	0.60**	0.43**	**1.00**

Note: Lower diagonal shows phenotypic correlations between diary measures.
Upper diagonal shows nonshared environmental (MZ differences) correlations between diary measures.

(r = –.37, p < .01) reporting less 'flow' in English lessons. There was no significant NSE relationship between peer stressors and 'flow' in Mathematics, Science or average day ratings. Within-pair differences in exposure to academic stressors did not correlate significantly with differences in 'flow' or positivity about school, but MZ differences in upset caused by academic stressors did (r = –.27, p < .05 with 'flow' in English; r = –.30, p < .05 with 'flow' in Mathematics; and r = –.30, p < .05 with average day ratings). MZ differences related to teacher–child relationships were not significant correlates of within-pair differences in 'flow' or positivity. In total, 5/24 correlations between stress and 'flow' / positivity were significant. Although this represents fewer significant correlations than we found at the phenotypic level the MZ difference method is a conservative one, rendering these findings of interest.

MZ differences in 'flow' were significantly correlated between subjects, reaching a peak of r = .82, p < .01 between Mathematics and Science. The twin reporting more 'flow' in one subject was also likely to be the twin reporting more 'flow' in another. Furthermore, MZ differences in 'flow' were significantly correlated with differences in positivity about the school day (r = .49, p < .01 to r = .65, p < .01).

Nonshared Environmental Correlations Between School Experience and School Achievement

We used our MZ differences design to explore the nonshared environmental relationship between our measures of school experience and school achievement. However, for purposes of comparison, Table 4 begins with phenotypic correlations based on just one member of each MZ pair (first set of columns labeled 'Individual differences correlations'). Results for the other member of the pair were highly similar. These phenotypic correlations indicate only a chance number of significant correlations between school experience and school achievement — only one of 33 correlations was significant at p < .05. Nonetheless, the larger correlations are in the expected direction: a correlation of –.29 (p < .05) between upset by academic stressors and Mathematics achievement, –.25 between upset by teacher and Mathematics achievement, and .22 between positive teacher interactions and English achievement.

However, turning to the second set of columns ('MZ differences correlations') which test for nonshared environmental links between experience and achievement, more significant nonshared environmental relationships were found when the sharper scalpel of differences within MZ pairs was used. Although the average day rating showed no significant phenotypic correlations with school achievement, MZ differences in average day rating showed significant correlations with MZ differences in school achievement for two of the three achievement measures. The within-pair correlation for MZ twins was .39 (p < .01, effect size = 15%) for Mathematics achievement and .29 (p < .01, effect size = 8%) for Science achievement. In other words, the twin who reported having a better day at school was the twin with higher Mathematics and Science achievement as rated by their teacher. It should be noted that although MZ differences include error of measurement, these nonshared environmental correlations between MZ differences in school experience and MZ

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Table 4

Correlating Experience with Achievement

	Individual differences correlations			MZ differences correlations		
	English	Math	Science	English	Math	Science
Total number of peer stressors	0.06	–0.12	0.08	–0.20	–0.29*	0.06
Upset caused by peer stressors	0.05	–0.10	0.12	–0.15	–0.23	0.05
Total number of academic stressors	–0.15	–0.14	–0.01	0.01	–0.09	0.23
Upset caused by academic stressors	–0.18	–0.29*	–0.09	–0.11	–0.24	–0.02
Total number of teacher stressors	–0.11	–0.18	–0.07	0.13	0.09	0.19
Upset caused by teacher stressors	–0.14	–0.25	–0.14	0.04	–0.02	0.15
Total positive teacher interactions	0.22	0.09	0.16	0.11	–0.13	0.11
Flow in English	0.06	0.01	0.04	0.15	0.13	0.20
Flow in Mathematics	0.11	0.09	0.11	0.03	0.08	0.17
Flow in Science	0.04	–0.04	–0.04	0.22	0.16	0.35*
Average day rating	–0.02	0.15	0.05	0.16	0.39**	0.29*

differences in school achievement would not be expected to include error of measurement.

For the other 30 correlations in Table 4, however, only 2 significant nonshared environment correlations emerged between the more specific measures of school experience and school achievement. As was the case for the average day rating, the nonshared environment correlations did not correspond to the between-pair correlations in Table 4. MZ differences in experience of peer stressors correlated significantly with MZ differences in teacher-rated Mathematics achievement ($r = -.29$, $p < .05$, effect size = 8%). That is, the twin who experienced more peer problems achieved less in Mathematics. MZ differences in 'flow' in Science correlated significantly with MZ differences in Science achievement ($r = .35$, $p < .05$, effect size = 12%).

We explored the nonshared environmental relationship between school experience and school achievement further with a stepwise multiple regression analysis. We entered MZ differences in average day rating in the first block, partly because it represents our only distal measure and partly because the MZ differences correlations presented in Table 4 suggested that it carries most weight. All proximal measures were entered into the regression in a second block.

As shown in Table 5, findings confirmed the MZ differences correlations. There were no significant NSE predictors of teacher-rated English achievement. However, MZ differences in average day rating accounted for 16% of the variance in MZ differences in teacher-rated Mathematics achievement. Proximal measures of the classroom environment did not add significantly to this and were excluded from the analysis. However, the strongest of the nonsignificant relationships was with MZ differences in peer problems, as would be expected from Table 4. Furthermore,

Table 5

Stepwise Multiple Regression Analysis of MZ Differences in Classroom Experience as Predictors of MZ Differences in Achievement

Adjusted R^2	Maths 0.16 ($p < 0.01$)		Science 0.10 ($p < 0.05$)	
	β	*t*	β	*t*
Block 1				
Average day rating	**0.42**	**2.98****	0.18	1.10
Block 2				
Total number of peer stressors	–0.20	–1.31	–0.01	–0.09
Upset caused by peer stressors	–0.13	–0.90	0.04	0.28
Total number of academic stressors	0.03	0.19	0.07	0.46
Upset caused by academic stressors	–0.10	–0.68	–0.14	–0.94
Total number of teacher stressors	0.14	0.99	0.20	1.36
Upset caused by teacher stressors	0.02	0.11	0.21	1.43
Total positive teacher interactions	–0.04	–0.26	0.01	0.08
Flow in English	–0.04	–0.25	–0.08	–0.32
Flow in Mathematics	–0.10	–0.67	–0.04	–0.17
Flow in Science	–0.03	–0.20	0.35	2.36*

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MZ differences in 'flow' in Science lessons significantly predicted 10% of the variance in MZ differences in Science achievement. Average day ratings, as well as positive and negative teacher experiences were the strongest of the measures excluded from the stepwise regression for Science achievement.

Discussion

Using a new telephone diary measure and a genetically sensitive design, we found that MZ differences in positivity about school significantly predicted MZ differences in Mathematics achievement, and that MZ differences in 'flow' in Science lessons significantly predicted MZ differences in Science achievement. Peer relationships emerged as a potential NSE influence on achievement to be explored in a larger study with more power to detect small effects. In contrast to previous research (Ainley & Bourke, 1992; Walker & Plomin, 2006), we did find significant relationships between aspects of the classroom environment and academic achievement. We think this is partly a result of using a richer measure of the environment and, perhaps more importantly, the MZ-differences design. We also replicated the finding that MZ twins who share a classroom experience that classroom differently (Oliver et al., 2008; Walker & Plomin, 2006).

It is remarkable that MZ twins experience the same classroom differently. These children share their genes and most of their environment, yet within-pair correlations for classroom stressors, 'flow' and positivity about school were all less than $r = .65$. How does one child come to perceive more problems with schoolwork and relationships than their genetically identical co-twin, to all intents and purposes their clone? Chance, as is always the case in NSE research, is one contender. If Adam does not concentrate during his Science test because he is upset about accidentally leaving his homework on the bus and getting in trouble with his teacher is his poor test score (relative to that of his identical twin, Tom) the result of chance? It is a plausible hypothesis. And yet, putting MZ differences simply down to chance seems unempirical. Perhaps what really matters is why or how Adam forgot his bag, how he managed the situation afterwards and how he reacted to the chain of events it set in motion. Examples of this sort lead us to propose personality as a mediator of such nonshared environmental experiences.

Environmental influences beginning at conception may influence the development of individual temperamental styles so that even identical twins like Adam and Tom may perceive similar worlds in different ways. Personality, as a mediator between NSE experience and behavioural outcome represents an exciting avenue for future research. The first step would be to collect personality temperament data from a large twin sample; use behavioural genetic methods to partition personality variance into genetic, shared environmental and nonshared environmental components; and then assess the extent to which personality mediates nonshared experiences.

The identification of influential NSE factors has been difficult (Plomin et al., 2001; Turkeimer & Waldron, 2000). As with the hunt for genes, the research so far indicates that behavior is influenced by many NSE experiences, usually of small effect size. Working with MZ twins — the cleanest way of looking for NSE — is like exploring parallel universes where every divergent step taken enhances each twin's individuality. Each fork in the road permits the growth of a mountain of divergent experience that is not necessarily systematic but which, on closer examination, may yet prove to be.

In terms of academic achievement our study has found links between MZ differences in positivity about school and MZ differences in Mathematics achievement; and MZ differences in 'flow' in Science and MZ differences in teacher-rated Science achievement. No significant predictors of differential achievement in English emerged. It is interesting that Science and Mathematics outcomes appear to be more strongly linked to the school environment than English. This finding will need to be explored in a larger study with greater power to detect small effects. It would also be interesting to conduct this study with younger children still learning to read, write and calculate, to see if the effect remains the same. Given that girls were generally more positive about school and 'flow' than boys it would also be interesting to explore gender differences in these effects in a larger study.

Nonetheless, the current study suggests that positivity about school, 'flow' and, at a nonsignificant but notable level, peer stressors are associated with achievement, working as NSE influences. We also saw significant NSE relationships between peer and academic stressors and 'flow; and between 'flow' and positivity about school, suggestive of a possible chain reaction. Future research, therefore, will focus on these measures with a large sample of identical and non-identical twins in order to explore effects at the extremes of experience and achievement; to analyze gender differences; and also to investigate potential genotype × environment effects. For example, is the heritability of achievement higher for children with the most peer problems or does NSE have a bigger impact on them than on the remainder of the distribution? At this early stage the research simply indicates that children who enjoy school more do better at school, particularly in Science and Mathematics. We cannot disentangle cause from effect but the implication is that making the classroom a happy and engaging place to be, perhaps by focusing on personalized learning given our evidence that the classroom is experienced differently even by very similar children, will pay off in terms of children's achievement levels.

We saw that stress appeared to be negatively associated with children's 'flow' and with their happiness at school even though MZ differences in stress, with

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the exception of peer problems and Mathematics, did not correlate significantly with MZ differences in achievement. However, as described earlier, 14/24 phenotypic correlations between classroom stress and 'flow' and average day rating (ADR) were significant. Many of these correlations had medium to large effect sizes. For example, the correlation between upset caused by academic stressors and 'flow' in Science was $r = .56$, $p < .01$, ES = 31%. The average correlation for peer stressors with the three 'flow' variables and ADR was $r = .38$, ES = 14%. Only teacher stressors yielded no significant correlations with 'flow' and positivity, although upset caused by teacher stressors did. Furthermore, 5/24 correlations were moderately significant at the more conservative level of nonshared environment.

Our study suggests the hypothesis that classroom stress, in terms of problems with friends, teachers and schoolwork, is associated with low morale in terms of 'flow' in lessons and positivity about the school experience and that this low morale has a negative knock-on effect on academic achievement. Exploration of this hypothesis will be the next step in our genetically sensitive exploration of the relationship between the classroom environment and children's achievement.

One limitation of the current research is the sample size, which is small by the standards of twin studies and behavioral genetic research. However, our sample has a unique power to identify measurable NSE influences which can later be measured and analyzed in the context of a full twin sample. A larger study would allow us to explore NSE relationships at the extremes of the experience and achievement distributions where stronger results have been found in previous research (Asbury et al., 2003). We believe our results are conservative because of a lack of statistical power but that the approach has served us well in identifying candidate environmental influences on academic achievement. A further limitation is that we have no means of disentangling the direction of effects. It may be that being positive about school is a byproduct of achievement rather than the other way around.

Our study has identified specific nonshared aspects of the classroom environment that significantly predict academic achievement. The challenge now is to replicate these results in a larger sample, to ask more subtle questions about gender, the extremes and interaction effects and, specifically, to test our hypothesis that classroom stress leads to low morale which, in turn, leads to reduced achievement. We also hope to explore the relationship between personality and experience which is distinct from the relationship between 'flow' and achievement as 'flow' is more likely to represent traits such as attention, self-regulation and task persistence, all known correlates of achievement, than personality traits.

By identifying the real-life experiences that constitute the NSE component of variance in academic achievement we hope to open a door to new empirically based educational interventions that may enhance achievement and, perhaps, reduce any negative impact of genetics or shared environments such as neighbourhood and poverty.

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