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Twin classroom dilemma: to study together or separately?

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Abstract

There is little research to date on the academic implications of teaching twins in the same or different classroom. Consequently, it is not clear whether twin classroom separation is associated with positive or negative educational outcomes. As a result, parents and teachers have insufficient evidence to make a well-informed decision when twins start school. This study addresses two research questions: Are there average positive or negative effects of classroom separation? Are twins taught in different classes more different from each other than twins taught in the same class? Twin pairs from two large representative samples from Quebec (Canada) and the UK were evaluated across a large age range (7 to 16 years) on academic achievement, several cognitive abilities and motivational measures. Our results show almost no sizeable positive or negative average effect of classroom separation on twins' achievement, cognitive ability and motivation. Twin pairs at age 12 (Quebec, Canada) and at age 16 (UK) were slightly more similar on achievement if placed in the same classroom, with slightly greater similarity among MZ twins than DZ twins. However, the few effects found were weak, and it remains unclear whether they result from classroom separation or other factors. These results suggest that in terms of educational outcomes, policymakers should not impose rigid guidelines to separate twin pairs during their education. The choice of whether to educate twin pairs together or separately should be up to parents, twins and teachers, in response to twins' individual needs.

Keywords: Twins, Classroom separation, Academic achievement, Motivation, Cognitive abilities, Educational policies

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Graphical Abstract (can be printed in black and white)

Twins at school: together or apart?

8705 Monozygotic and Dizygotic twin pairs followed from early school years to age 16



Percentage of MZ & DZ twins taught in the same class

Percentage of MZ & DZ twins taught in different classes

At age 7:

65.90%

34.10%



At age 16:

28.20%

71.80%



- No differences in achievement and cognitive abilities at ages 7, 9, 10, 12 and 14 and in motivation at ages 9 between twins taught together vs separately
- At age 12 twins taught together are slightly more motivated in Math (.2% effect size)
- At age 16, twins taught together are slightly better in Math exams (2.8% effect size) than twins taught separately
- These differences might be due to ability streaming

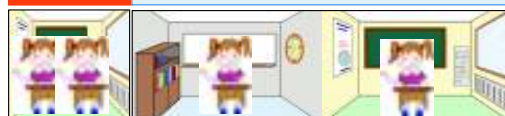
426 Monozygotic and Dizygotic twin pairs followed from early school years to age 12



At age 7:

24.40%

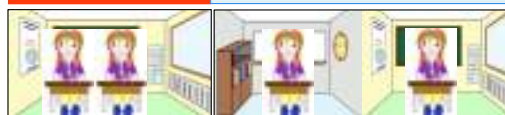
75.60%



At age 12:

39.70%

60.30%



- No differences in achievement at ages 7, 9, and 10 and in motivation at age 10, between twins taught together vs separately
- At age 12 twins taught together are slightly better in achievement (1.9% effect size) and slightly more motivated in Math (2% effect size)
- At age 12 the percentage of UK twins taught together vs separately is very similar to the Canadian percentage at the same age: 33.50% vs 66.50%

The choice of whether to educate twin pairs together or separately should be up to parents, twins and teachers, in response to twins' individual needs

Twin Classroom Dilemma: to Study Together or Separately?

The twin and multiple birth association (TAMBA) in the United Kingdom (UK), recommend that the decision of whether to educate twin pairs separately or together should be one made by parents and teachers (TAMBA, 2009; 2010). Separation might have positive consequences: aiding development of individual identities, reducing inter-twin competition (Segal & Russell, 1992), and decreasing dependency, especially where dominant-dominated relationships occur (Lalonde&Moisan, 2003). Separating twins also helps teachers and other class members to distinguish between the pair.

Conversely, the arguments against separation are also strong. A recent study found that twinship may have a positive effect on longevity, similar to a documented positive effect of marriage on longevity (Sharrow & Anderson, 2016). It is possible that the protective effect of twinship results from the unique bond held between twin pairs. Indeed, separation from their co-twin at the beginning of school may have adverse emotional consequences considering the proximity that twins have shared all their lives up to this point (e.g. Van Leeuwen, Van Den Berg, van Beijsterveldt, & Boomsma, 2005; Tully, Moffitt, Caspi, Taylor, Kiernan, & Andreou, 2004). Early classroom separation might increase separation anxiety, co-twin preoccupation, and desire to be with their co-twin, which may reduce school enjoyment (Lalonde & Moisan, 2003). Twins attending different schools could also contribute to family stress as getting both twins to school on time might cause logistical problems for parents.

On the other hand, choice for separation may reflect twins' interests/suitability for a specialised school or program (e.g. specialised music school or schools with enhanced mathematics curricula). It may also reflect imposed selection processes of setting or streaming to different schools/classes by ability. Indeed, children may be placed in the same class/program when they are equally matched on skill, drive, or talent, and separated (e.g.,

into advanced vs. remedial classes) when they differ markedly on these phenotypes. For twins, this may result in a higher number of separated non-identical twins (dizygotic; DZ) compared to identical twins (monozygotic; MZ) as MZ twins are more similar in ability (Petrill, Kovas, Hart, Thompson, & Plomin, 2009) and motivation (Spinath, Spinath, & Plomin, 2008). Consequently, this could increase the likelihood of MZ twins to enrol in the same program as a matter of choice and/or selection processes.

Average Classroom Separation Effect on Twins Abilities

A summary of previous studies investigating whether, on average, educating twins in the same vs. separate classrooms was associated with twins' abilities is given in Table 1. One study of Australian and US twins found no significant differences in literacy across kindergarten and 1st grade after pre-existing differences in disruptive behaviour and pre-literacy ability were taken into account (Coventry et al., 2009). Similarly, another study investigating the effect of separation on twins' achievement using the Netherlands Twin Registry (NTR) found no difference between separated and non-separated twin pairs at age 12 (Polderman et al., 2010). Twins taught together or separately did not differ on an independent national academic achievement test taken at the end of elementary school (CITO) (controlling for zygosity, familial SES, externalising problems at age 3, and urbanisation).

However, a study from a large Netherlands' educational survey collected longitudinally across Grades 2 (aged 6 years) to 8 (aged 12 years) reported significantly lower language ($d = 0.02$) and arithmetic ($d = 0.23$) scores for separated twins in early school years, especially for same-sex pairs. These effects were found even after controlling for peers' test scores, school and familial SES - potential indicators of non-random class placement (Webbink, Hay, & Visscher, 2007). However, no significant effect was found at age 12, suggesting no long-lasting effect of early separation. Similarly, a longitudinal study investigated the effects of classroom separation in UK twins at ages 5 and 7 years. Twins were divided into three groups: 1) pairs who were taught together at both ages; 2) pairs who

were taught together at age 5 and separately at age 7; and 3) pairs who were separated at both ages (Tully et al., 2004). The results showed significant but small effect sizes of classroom separation at age 7 only (see Table 1). Both MZ and DZ twins separated at age 7 had lower reading scores.

Do Separated Twins Perform More Differently From Each Other?

Previous studies have also tested whether twins educated separately perform more differently to each other than twins educated together. One UK study compared mean differences between twins educated together vs. separately and found that twins educated separately were marginally more different than twins educated together. This was found for school achievement and cognitive abilities, such as verbal and non-verbal reasoning at ages 7, 9 and 10 years (Kovas, Haworth, Dale, & Plomin, 2007). However, this pattern was not observed for academic motivation. UK twins in different classrooms were no more dissimilar in their academic motivation than twins in the same classrooms at age 9 (Kovas et al., 2015). A similar study of Australian and US twin pairs from kindergarten to 2nd grade showed slightly larger mean differences for twin pairs taught separately compared to those taught together across time, with larger differences shown for DZ compared to MZ twins.

Additionally, lower correlations were found for both MZ and DZ twins taught separately (Byrne et al., 2010). Classroom separation status explained a modest percentage (8%) of the variance in literacy and this was not due to initial differences in literacy between the pairs. The slightly smaller similarity for separated twins (than for twins educated together) may result from differences in teacher-student relationships, quality of instruction and emotional support, or peer relations (Hamre & Pianta, 2005). However, research investigating mean differences between twin pairs has shown that these factors may also lead to dissimilarity in achievement for twins taught together as they each perceive the same classroom differently (Asbury, Almeida, Hibel, Harlaar, & Plomin, 2008).

To sum up, previous studies suggest inconsistent and very modest average effects of twins' classroom separation in elementary school years (see Table 1). As a result, parents and educational policymakers are left without clear evidence for educating twins separately or together. Consequently, more research into the implications of twin separation is needed.

The inconsistencies of previous research may mean that effects of classroom separation differ across different measures, samples and year/stage of education. Previous research has also suffered from a number of limitations. Firstly, most studies assessed three data points or less. Some time points were quite close in age, covering a short developmental period. Secondly, few studies investigated the effect of classroom separation by twin's sex and zygosity which precluded an investigation of whether the effects of separation are stronger as a function of genetic similarity (e.g. MZ vs. DZ twins) and sex differences between twins (e.g. male vs. female twins). Thirdly, most previous studies investigated classroom separation in one country only, limiting their interpretations to one educational policy/system and culture.

Here, we extend the results from previous research by investigating the average effect of classroom separation on three educational outcomes: school achievement, motivation and cognitive ability. We also investigate whether separated twins perform more differently to each other than those in the same classroom. Achievement, motivation and cognitive ability are associated with each other, including through partially shared etiology and reciprocal developmental links (e.g. Spinath et al., 2006; Malanchini et al., 2017). Therefore, it can be expected that similar effects of separation will be observed for all three traits.

We also extend results of previous research by investigating in two large representative twin samples from the UK and Quebec (Canada). These samples represent two different education systems with differences in policy for twin separation. In Quebec (Canada), separation of twin pairs is widespread. Canada's policy for classroom placement of multiple births is to leave the decision to parents, although separating twins is sometimes

strongly encouraged by the School Commission Boards (Lalonde & Moisan, 2003). In the UK, parents can mostly choose whether or not to send twins to the same class. A recent survey of 514 UK parents of twin pairs aged up to 3 years showed that 60% of MZ and 55% of DZ twins' parents wanted to keep the twins together when they start school (Cherkas, 2015). However, in around 20% of cases, schools have a stringent policy to separate twins and/or triplets without consultation or supporting evidence that this would be in the children's best interests (Cherkas, 2015).

In the present study, twins were followed longitudinally from ages 7 to 16 years, which span the elementary and high school education in the UK and Quebec, Canada. The study addresses two main research questions: 1) Are there average positive or negative effects on school achievement, cognitive ability and academic motivation of twins, associated with being in the same vs. different classroom; and do the effects vary as a function of twins' sex and/or zygosity, and the timing of separation? (2) Are twins taught in different classes more different from each other in achievement, cognitive ability and academic motivation than twins taught in the same class? In addition, are these differences greater for DZ twins than MZ twins, reflecting greater initial genetic and/or environmental differences for DZ twins?

Methods

Participants

The two representative samples taking part in the study are: the UK Twins Early Development Study (Haworth, Davis, & Plomin, 2012), which provided data between ages 7 and 16 years from 8705 twin pairs (3039 MZ and 5666 DZ pairs) following exclusion of data from participants with medical issues and English spoken as a second language; and the Canadian French and/or English speaking Quebec Newborn Twin Study (QNTS; Boivin et al., 2013), which provided data from 426 twin pairs (182 MZ and 244 DZ pairs) between ages 7 and 12 years. In both samples, participant numbers vary across measures and time of

data collection. Further information about the samples is provided in Supplementary Online Material (SOM) Sample description section. Ethical approval was obtained from the UK Medical Research Council, since 1995 (G9424799, G0500079, and now G0901245); Twins Early Development Study (TEDS), and from the Sainte-Justine Hospital Research Centre (2009-202, 2764); Quebec Newborn Twins Study (QNTS).

Educational System. UK and Quebec education systems are mostly similar with some differences in teacher/classroom allocation across the school years. In both Quebec and the UK the same teacher teaches all subjects for students during elementary education, with the teacher changing on a yearly basis. In Quebec, elementary education starts at age 5-6 and continues to age 12 (Grade 6), whereas in the UK, elementary education starts at age 4-5 and continues to age 11 (Year 6). In high school, the majority of the UK schools' mathematics and English classes are selected based on students' ability in these subjects, while there is no such selection in Quebec, except for optional advanced classes for English.

Measures and Procedure

A broad range of achievement, cognitive and motivational measures were used across all samples. These measures are briefly summarised here, with details and the overall sample size for the UK twin study in Tables S1a-S1b in SOM.

Taught Together or Taught Separately. To determine whether twin pairs were taught together or separately, teacher contact details for each twin were used from the studies' admin data for ages 7 to 12 years (QNTS) and ages 7 to 14 years (TEDS). UK twins also self-reported retrospectively if they were in the same class as their co-twin at age 16 for English and mathematics, generating two different classroom separation variables at this age (one per school subject). These teacher reports and twins' self-report gave a reliable indication of whether or not twins had the same or different teacher.

Achievement. Academic achievement data were collected by teacher report across both samples. In QNTS, teachers assessed the twins' achievement at ages 7, 9, 10 and 12

years by answering the question: “How would you rate this child’s current academic achievement (in reading, writing, mathematics, and in general)?” Rating was given on a 5-point Likert’s scale ranging from 1 (near the bottom of the class) to 5 (near the top of the class). According to their strong correlations (mean correlations ranging between .78 and .82), average scores of academic achievement were then computed across school subjects at each age. In TEDS (UK), teachers reported children’s level of achievement in mathematics, and English at ages 7, 9, 10, 12, and 14 from tests that are set and marked by the teacher according to National Curriculum (NC) guidelines. The test scores contribute towards an overall level for each subject which ranges from 1-4, 1-5, and 1-7 depending on guidelines at the time of the study (1 being the lowest level). Again, composite scores of achievement were derived by averaging scores across school subjects, i.e. mathematics and English (average correlations ranging between .73 and .82), at each measurement time.

At age 16, UK participants reported their own grades for internationally recognised exams, General Certificate of Secondary Education (GCSE). These exams are taken for each specific subject at age 16 (here mathematics and English), which at the time of data collection was the end of compulsory education in the UK. The exams are graded A* to G with A* being the highest. Obtaining at least grade C is necessary for many further study/career options. Assessment guidelines can be accessed here:

<https://www.gov.uk/government/consultations/gcse-subject-content-and-assessment-objectives>.

Cognitive Ability. Cognitive ability was assessed in the UK sample at ages 7, 9, 10, 12 and 14 years using a composite measure of general cognitive ability (g). This was comprised of averaging across scores from verbal and non-verbal ability assessments at each age. Verbal ability was evaluated using a combination of age appropriate tasks from Wechsler Intelligence Scale For Children (WISC III: Wechsler, 1992). Additional verbal tests were included at ages 9, 10 and 12 from WISC-III as a Process Instrument (WISC-III-PI: Kaplan,

Fein, Kramer, Delis, Morris, 1999) (see Table S2 in SOM).

Non-verbal ability was also evaluated using WISC III tasks at ages 7, 10 and 12 years. Additional tests were included at age 7 from McCarthy Scales Of Children's Abilities (MCSA: McCarthy, 1972), and at age 12 from Raven's Standard Progressive Matrices (Raven, Court & Raven, 1996). Non-verbal ability was assessed at age 9 using Cognitive Abilities Test 3 (CAT3: Smith, Fernandes & Strand, 2001). At age 14, an expanded version of the age 12 Raven's Standard Progressive Matrices task was used (Raven et al., 1996). A full description of the tasks can be found in Kovas et al., (2007).

Motivational Constructs. Academic motivation was self-reported by the children in both samples. In the QNTS, children self-reported their enjoyment, and how they perceived their ability in mathematics and reading at ages 10 and 12 with six items from the Elementary School Motivation Scale (Guay et al., 2010). Items for enjoyment included: I like mathematics/reading; mathematics/reading interest me a lot; I do mathematics/reading even when I am not obliged to do so. Items for self-perceived ability (SPA) included: mathematics/reading is easy for me; I have always done well in mathematics/reading; I learn things quickly in mathematics/reading. Children answered each item using a 4-point Likert scale ranging from 1 (never) to 4 (always). We averaged the enjoyment and self-perceived ability scores for each school subject separately at age 10 and 12.

In TEDS, children completed the motivational tasks by a combination of booklet completion at age 9, and by web-based testing at age 12. Children self-reported their enjoyment (How much do you like?) and self-perceptions of ability (How good do you think you are at...?) with a six item measure (Spinath, Spinath, Harlaar, & Plomin, 2006). Participants were asked to rate their enjoyment and perceptions of ability on a 5-point scale (1 = like very much/very good, and 5 = don't like at all/not good at all) for three aspects of mathematics: solving number and money problems; doing mathematics in your head; and multiplying and dividing; and three aspects of English: reading; writing; and spelling. Again,

the enjoyment and self-perceived ability scores were averaged for mathematics and for English at each time point.

Although the measures were not identical across the samples, they tap into achievement and motivational constructs. As a consequence, similarity of results across the samples increases confidence in their generalizability.

Analyses

Average Effect of Classroom Separation. Analyses were conducted using one twin selected randomly from each pair, and within each sample on variables corrected for age, with outliers ($\pm 3SD$) removed. Descriptive analyses assessed frequency of twins in the same vs. different classes. Chi-square analysis assessed frequency differences of groups as a function of same/different class and zygosity. Analyses of variance (ANOVA) were conducted to assess potential differences in means for three dependent variables: achievement; cognitive ability; and motivation, as a function of three independent variables: same vs. different classes; zygosity; and sex by zygosity.

Similarity Among Twin Pairs. Further ANOVAs were conducted on absolute mean difference scores between twins of a pair to assess whether twins taught together were more similar in achievement, cognitive ability and motivation than those taught separately. Smaller absolute mean difference scores indicate greater similarity between twins of a pair, while greater absolute mean difference scores indicate less similarity, i.e. greater differences between twins of a pair. We also tested within-pair similarity using intra-class correlations.

Results

Frequency of Separation

Most Quebec twins were in different classes between ages 7 and 12, with only 24%-39% taught in the same class, while most UK twin pairs (65.9%) were taught together at age 7, but only 28% were in the same class by age 16 (see Tables 2a, 2b, and 2c). In both samples, the proportion of twin pairs taught together was slightly higher for MZ than DZ twins at all

ages. Chi-square tests of separation by zygosity showed no differences in the Quebec sample across all ages. In the UK sample, differences were not present at ages 7, 9, 10, and 14, but at age 12 and 16 more DZ twins than MZ twins were in different classes (age 12: $\chi^2 = 11.967, p < .001$; age 16: English, $\chi^2 = 82.564$, and mathematics, $\chi^2 = 51.637$). All effect sizes were small, with the greatest effect of 4.4%.

Average Effects of Classroom Separation

Means and standard deviations (SD) for achievement, motivation and cognitive ability at ages 7, 9, 10, 12, 14, and 16 by same or different teacher can be found in Tables S2 to S5 in SOM for the whole sample, the five sex by zygosity groups, and zygosity.

The patterns of results were very similar for twins taught separately and together across zygosity groups. ANOVAs (presented in Table 3 for achievement, Table 4 for cognitive ability and Table 5 for motivation) showed no differences for most measures between same vs. different class groups. A few differences were found, although with very weak effect sizes (ranging from 0.2% to 2.8%). The biggest effect of 2.8% was observed for mathematics GCSE (UK), with twins taught in the same class performing better than those in different classes. Results of ANOVA for sex and zygosity are presented in Tables 3, 4 and 5. Although some significant differences between the sex by zygosity groups were found, effect sizes were weak (ranging from 0.5% to 4.5%).

Additional analyses were performed to test whether there was a cumulative effect of classroom separation on twins' achievement and motivation across their years of education from age 7. Tables S6 and S7 in SOM present the percentage of twins who were educated in the same classrooms most of their school years vs. twins in different classes most of their school years. We conducted ANOVAs on achievement and motivational constructs at age 12 (Quebec), and on mathematics and English at age 16 (UK) by twins taught together or separately for most of the time (up to age 14 in the UK). See Tables S6 and S7 for group partitioning. For both samples, the results revealed no significant differences between these

two groups: this was the case for both MZ and DZ twins (see Table S8 in SOM), suggesting no cumulative average effect of classroom separation.

Similarity (or difference) Among Twin Pairs Taught Together vs. Separately

Because some weak average effects of separation were suggested at age 12 (Quebec), and 16 (UK), additional ANOVAs were conducted at these ages to test whether twin pairs taught together were more similar to each other than those taught separately. We computed the absolute difference in scores between twin and co-twin in each pair for all constructs of the Quebec sample at age 12; and for mathematics and English GCSE grades of the UK sample at age 16. We applied a log-10 transformation on the absolute difference scores to correct for non-normality. The transformed variables were also corrected for age and outliers ($\pm 3SD$) removed (see Figure S1-S5 in SOM). Using the transformed within-pair difference scores, we next conducted ANOVAs on the absolute mean difference scores by same vs. different classrooms and zygosity; and by same vs. different classrooms and sex by zygosity (see Table 6). Within-pair differences (or similarity) by zygosity and same vs. different classrooms are illustrated in Figures 1, 2, and 3.

Overall, we found smaller absolute mean difference scores (i.e., greater twin similarity) for those taught together than separately (see Figures 1, 2 and 3). Greater similarity was found for MZs than DZs, with the greatest difference shown for DZs taught separately. However, the effects were weak: 2.7% for achievement at age 12 (Quebec, Canada) and 3.4% for GCSE at age 16 (UK). While small significant differences were found between sex and zygosity groups, (3.2% to 11%), these did not differ as a function of same vs. different classroom (see Table 6). In general, similarity was greater for twins taught together than apart. This conclusion was also supported by MZ and DZ intra-class correlations (ICCs), showing slightly greater ICCs for twins taught together than separately (see Table S9 in SOM).

Discussion

The aim of this study was to examine the average effect of classroom separation on school achievement, cognitive ability, and academic motivation; and if average effects were found, to further test whether twins taught separately perform more differently from each other than those taught together. Our results showed almost no average effect of classroom separation, or cumulative effect of separation across years of education. These results were consistent across ages and countries, and across sex and zygosity. The only significant differences found between twins taught together and separately were at age 12 (Quebec, Canada) and at 16 (UK), which showed a weak average effect in favour of educating twins together. Moreover, twin pairs at age 12 (Quebec, Canada) and at age 16 (UK) were slightly more similar on achievement if placed in the same classroom, with slightly greater similarity among MZ twins than DZ twins.

Beyond the separation per se, the small but significant effect of being taught in different classes at age 16 (UK) may result from setting and streaming by ability processes. However, this is unlikely to explain the weak classroom separation effect in Quebec-Canada at age 12, as the Quebec education system does not apply streaming/selection processes. In the UK, students are streamed for ability at age 16, and therefore, are more likely to be taught separately as a result of different subject choices and differences in ability. This is particularly true of DZ twins as they are usually less similar phenotypically than MZ twins (Petrill et al., 2009; Spinath, Spinath et al., 2006) and for this reason might end up in separate classrooms more often than MZ twins.

Indeed, we found larger numbers of DZ than MZ twin pairs taught separately at age 16 in the UK, whereas the numbers were similar across zygosity groups for prior years in Quebec and the UK. The proportion of DZ twins taught separately compared to MZ twins was slightly larger for mathematics (DZ: 79% vs. MZ: 59.2%) than for English (DZ: 80.6% vs. MZ: 65.5%), and the effect of classroom separation was greater for mathematics than for English. This might reflect the greater genetic overlap found between intelligence and

mathematics performance, than between intelligence and other academic subjects, (Rimfeld, Kovas, Dale & Plomin, 2015). Therefore, ability streaming/selection related separation effects may be particularly evident in mathematics.

The present investigation also highlights both similarities and differences in classroom separation between Quebec (Canada) and the UK. In Quebec, a greater proportion of twins were taught separately at the beginning of elementary school, while in the UK at this stage of education, a greater proportion of twins were taught together. By age 12, the proportions of twins taught separately were similar across the two countries. This likely reflects differences in educational policies for the two countries. In Quebec, the School Commission Boards strongly encourage separation of twins when they begin education (Lalonde & Moisan, 2003) whereas separation in the UK occurs later on in secondary education/high school, potentially as a result of ability selection.

Nevertheless, despite the weak effects of classroom separation at age 12 (Quebec, Canada) and at age 16 (UK), our findings mostly corroborate previous research that found no significant average differences between twin pairs taught together or separately for school achievement (Coventry et al., 2009; Kovas et al., 2007; Polderman et al., 2009); cognitive abilities (Kovas et al., 2007); and academic motivation (Kovas et al., 2015), as well as no cumulative effect of separation (Kovas et al., 2015; Webbink et al., 2007).

Overall, although previous research found significant average effects of classroom separation—especially in the early years, at ages 5 and 6 (Tully et al., 2004; Webbink et al., 2007), well-powered studies found negligible or small effects of classroom separation at age 7. Inconsistencies in previous studies could be due to differences in samples (e.g., spurious effects in unrepresentative samples). It is also possible that other aspects of the classroom environment, such as quality of instruction or peer relations, may buffer any effect of separation on achievement (e.g. Hamre & Pianta, 2005). Finally, as twins' classroom allocation is usually a result of discussion between parents, teachers and the twins themselves, any

potential ill effects of assignment may be attenuated, or potentially be present only if decisions were determined by high-level school policy beyond family and teacher control.

Although we found no substantial average classroom separation effect, this does not mean an absence of effect for the individual. Effects of classroom separation are likely to depend on individual characteristics and different perceptions of classroom experience (e.g. Asbury et al., 2008). Other factors such as socio-emotional difficulties (e.g. Van Leeuwen et al., 2005; Tully et al., 2004), ability streaming or school transition might also play a role beyond classroom separation.

Limitations and Future Research

The study is not without limitations. First, it is important to mention that the study is not a randomized controlled trial (RCT) of twins' classroom placement. Instead, it is a naturalistic study of twins' classroom allocation, where allocation is likely to be the result of discussion between parents, teachers and the twins themselves. Second, we were not able to fully test the patterns of results across both samples up to age 16, as data were not available at age 16 in the Quebec sample. Similarly, we only had available data for GCSE at age 16 in the UK sub-sample that provided same/different teacher data. Therefore we were unable to assess any effect of same/different teacher on cognitive ability or motivation at this age. Third, attrition for both samples also resulted in some non-overlapping data across the years of the study and so prevented further longitudinal analyses to show potential effects for consecutive years of being in the same vs. different classes. Fourth, other traits, such as emotional or behavioural outcomes may show a different pattern of results and therefore need to be explored in future research. Fifth, the results of this study should not be generalized to other countries/systems. Despite some differences between the two educational systems, the cultures investigated here are very similar. Future studies would benefit from investigating across more diverse cultures and education systems.

Finally, in both countries, teachers reported twins' school achievement. It is possible that teachers of twins in the same classroom rated twins more similarly than teachers of twins in separate classrooms. Teacher rater-bias could especially be a limitation in the UK where the national curriculum tests on which these assessments were based were set and marked by the teachers. However, the small effects of classroom separation and within-pair similarity found at age 16 (UK) are unlikely to be the result of teacher rating reliability, as at this age, achievement was measured by externally assessed exams.

Conclusion

Our results show no sizeable positive or negative average effect of separation on twins' achievement, cognitive ability and motivation. The few effects found were weak and could stem from other factors rather than a real effect of classroom separation. These results suggest that in terms of academic achievement, cognitive ability and motivation, policymakers should not impose rigid guidelines for schools and parents to separate twin pairs during their education. The choice of whether to educate twin pairs together or separately should be up to parents, twins and teachers, in response to twins' individual needs.

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Table 1. Summary of previous research investigating separation and non-separation of twin pairs in the classroom

Authors (year)	Sample size	Age of sample	Significant difference of same/different classrooms	Effect size	Analyses by zygosity
Asbury et al., (2008)	122 twins (61 MZ pairs)	10 years	Effect for twin pairs within same classroom in school achievement	8-15% science and mathematics achievement	MZ only
Byrne et al., (2010)	1422 twins (355 MZ; 356 DZ pairs)	54–71 months	S>D literacy	Literacy: 8% of variance explained by classroom separation status	MZ vs DZ
Coventry et al., (2009)	1505 individual twins/triplets (752 MZ; 752 DZ)	59-77 months	No significant difference for literacy	None	MZ vs. DZ
Kovas et al., (2007)	11482 twins (~1910 MZ; ~3830 DZ pairs)	7, 9, &10 years	No significant difference for school achievement or cognitive ability	None	MZ vs DZ
Kovas et al., (2015)	2294 twins (~382 MZ; ~764 DZ pairs)	9 years	Non significant difference for motivation	None	MZ vs DZ
Polderman et al., (2010)	4006 twins (839 MZ; 1164 DZ pairs)	12 years	No significant difference for school achievement	None	Zygosity; Sex; Classroom separation by zygosity.
Tully et al., (2004)	1756 twins (484 MZ; 394 DZ pairs)	5 &7 years	S>D reading D>S internalizing problems	Internalizing problems: Separated early: age 5: MZ ($d=0.4$); DZ ($d=0.2$) age 7: MZ ($d=0.3$); DZ ($d=0.1$) Separated late: age 5: MZ ($d=0.4$); DZ ($d=0.3$) age 7: MZ ($d=0.4$); DZ ($d=0.2$) Reading at age 7: Separated early: MZ ($d=0.1$); DZ ($d=0.1$) Separated late: MZ ($d=0.2$); DZ ($d=0.1$)	MZ vs DZ
Webbink et al., (2007)	5756 twins (2878 pairs)	6–12 years	S>D language and arithmetic at age 6	Language: $d=0.02$ Arithmetic: $d=0.23$	None

Table 2a. Quebec twin pairs taught by the same or different (S/D) teachers by sex and zygosity; and by zygosity at ages 7 to 12 years

Age	S/D teacher	MZm	DZm	MZf	DZf	DZos	MZ	DZ	Total
Age 7	Different	74.7% n=65	79.1% n=53	70.5% n=67	74.6% n=44	78.8% n=93	72.5% n=132	77.9% n=190	75.6% n=322
	Same	25.3% n=22	20.9% n=14	29.5% n=28	25.4% n=15	21.2% n=25	24.5% n=50	22.1% n=54	24.4% n=104
	Total	100% n=87	100% n=67	100% n=95	100% n=59	100% n=118	100% n=182	100% n=244	100% N=426
Age 9	Different	71.6% n=59	72.9% n=43	63.5% n=54	72.1% n=44	72.4% n=76	77.2% n=125	76.3% n=167	70.3% n=275
	Same	28.4% n=23	27.1% n=16	36.5% n=31	27.9% n=17	27.6% n=29	22.8% n=37	23.7% n=52	29.7% n=116
	Total	100% n=81	100% n=59	100% n=85	100% n=61	100% n=105	100% n=162	100% n=219	100% N=391
Age 10	Different	71.6% n=58	72.9% n=43	63.5% n=54	72.1% n=44	72.4% n=76	67.5% n=122	72.4% n=167	70.3% n=275
	Same	28.4% n=23	27.1% n=16	36.5% n=31	27.9% n=17	27.6% n=29	32.5% n=54	27.6% n=62	29.7% n=116
	Total	100% n=81	100% n=59	100% n=85	100% n=61	100% n=105	100% n=166	100% n=255	100% N=391
Age 12	Different	57.6% n=38	57.4% n=35	59.1% n=52	64.9% n=37	62.2% n=69	58.4% n=90	61.4% n=140	60.3% n=231
	Same	42.4% n=28	42.6% n=26	40.9% n=36	35.1% n=20	37.8% n=42	41.6% n=64	38.6% n=88	39.7% n=152
	Total	100% n=66	100% n=61	100% n=88	100% n=57	100% n=111	100% n=154	100% n=228	100% N=383

MZm = monozygotic male; MZf = monozygotic female; DZm = dizygotic male; DZf = dizygotic female; DZos = dizygotic opposite sex; MZ = all monozygotic; DZ all dizygotic. Significant results in bold at $p \leq .05$.

Table 2b. UK twin pairs taught by the same or different (S/D) teachers by sex and zygosity; and by zygosity at ages 7 to 12 years

Age	S/D teacher	MZm	DZm	MZf	DZf	DZos	MZ	DZ	Total
Age 7	Different	36.5% n=404	37.3% n=393	32.7% n=420	31.7% n=361	33.4% n=702	34.4% n=824	33.9% n=1456	34.1% n=2280
	Same	63.5% n=702	62.7% n=662	67.3% n=866	68.3% n=778	66.6% n=1398	65.6% n=1568	66.1% n=2838	65.9% n=4406
	Total	100% n=1106	100% n=1055	100% n=1286	100% n=1139	100% n=2100	100% n=2392	100% n=4294	100% N=6686
Age 9	Different	42.0% n=238	42.8% n=229	39.4% n=273	40.1% n=234	42.4% n=452	40.6% n=511	41.9% n=915	41.4% n=1426
	Same	58.0% n=328	57.2% n=306	60.6% n=420	59.9% n=350	57.6% n=613	59.4% n=748	58.1% n=1269	58.6% n=2017
	Total	100% n=566	100% n=535	100% n=693	100% n=584	100% n=1065	100% n=1259	100% n=2184	100% N=3443
Age 10	Different	45.6% n=241	49.3% n=252	43.2% n=293	47.1% n=269	46.8% n=504	44.2% n=534	47.5% n=1025	46.3% n=1559
	Same	54.4% n=288	50.7% n=259	56.8% n=386	52.9% n=302	53.2% n=574	55.8% 674	52.5% 1135	53.7% n=1809
	Total	100% n=529	100% n=511	100% n=679	100% n=571	100% n=1078	100% n=1208	100% n=2160	100% N=3368
Age 12	Different	66.4% n=725	67.7% n=710	61.6% n=792	61.5% n=715	71.6% n=1535	63.8% n=1517	68.0% n=2960	66.5% n=4477
	Same	33.6% n=367	32.3% n=339	38.4% n=493	38.5% n=447	28.4% n=608	36.2% n=860	32.0% n=1394	33.5% n=2254
	Total	100% n=1092	100% n=1049	100% n=1285	100% n=1162	100% n=2143	100% n=2377	100% n=4354	100% N=6731

MZm = monozygotic male; MZf = monozygotic female; DZm = dizygotic male; DZf = dizygotic female; DZos = dizygotic opposite sex; MZ = all monozygotic; DZ all dizygotic. Significant results in bold at $p \leq .05$

Table 2c. UK twin pairs taught by the same or different (S/D) teachers by sex and zygosity; and by zygosity at ages 14 to 16 years

Age	S/D teacher								Total
		MZm	DZm	MZf	DZf	DZos	MZ	DZ	
Age 14	Different	79.4%	73.9%	70.3%	71.8%	78.9%	74.1%	75.7%	75.1%
		n=108	n=88	n=130	n=112	n=195	n=238	n=395	n=633
	Same	20.6%	26.1%	29.7%	28.2%	21.1%	25.9%	24.3%	24.9%
		n=28	n=31	n=55	n=44	n=52	n=83	n=127	n=210
	Total	100%	100%	100%	100%	100%	100%	100%	100%
		n=136	n=119	n=185	n=156	n=247	n=321	n=522	N=843
Age 16 English	Different	67.8%	80.7%	63.5%	72.5%	84.8%	65.5%	80.6%	75.5%
		n=202	n=230	n=216	n=240	n=530	n=418	n=1000	n=1418
	Same	32.2%	19.3%	36.5%	27.5%	15.2%	34.5%	19.4%	24.5%
		n=96	n=55	n=124	n=91	n=95	n=220	n=241	n=461
	Total	100%	100%	100%	100%	100%	100%	100%	100%
		n=298	n=285	n=340	n=331	n=625	n=638	n=1241	N=1879
Age 16 Math	Different	63.5%	76.3%	55.3%	76.5%	81.5%	59.2%	79.0%	72.2%
		n=190	n=219	n=188	n=254	n=507	n=378	n=980	n=1358
	Same	36.5%	23.7%	44.7%	23.5%	18.5%	40.8%	21.0%	27.8%
		n=109	n=68	n=152	n=78	n=115	n=261	n=261	n=522
	Total	100%	100%	100%	100%	100%	100%	100%	100%
		n=299	n=287	n=340	n=332	n=622	n=639	n=1241	N=1880

MZm = monozygotic male; MZf = monozygotic female; DZm = dizygotic male; DZf = dizygotic female; DZos = dizygotic opposite sex; MZ = all monozygotic; DZ = all dizygotic. Significant results in bold at $p \leq .05$.

Table 3. Achievement: ANOVA results by zygosity, sex and by having the same or different (S/D) teachers

Age	Country	Construct	S/D teacher		Zygoty*S/D		Zygoty*Sex		Sex, Zygoty*S/D	
			<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2
7	Quebec-Canada	Achievement	.363	.003	.146	.007	.166	.021	.488	.011
	UK	Achievement	.043	.001	.774	.000	.000	.005	.159	.001
9	Quebec-Canada	Achievement	.866	.000	.399	.002	.407	.011	.726	.006
	UK	Achievement	.184	.001	.969	.000	.044	.004	.943	.000
10	Quebec-Canada	Achievement	.382	.002	.691	.000	.002	.045	.392	.011
	UK	Achievement	.267	.000	.832	.000	.260	.002	.432	.001
12	Quebec-Canada	Achievement	.016	.019	.106	.009	.045	.032	.128	.023
	UK	Achievement	.442	.000	.763	.000	.139	.002	.158	.002
14	UK	Achievement	.680	.000	.353	.002	.520	.008	.173	.016
16	UK	Math	.000	.028	.104	.002	.207	.001	.469	.002
		English	.000	.008	.303	.001	.000	.019	.180	.004

One twin selected randomly. Bold indicates significance at $p < .05$. Composite scores at all ages apart from age 16 UK.

Table 4. Cognitive ability G composite: ANOVA results for the UK twins from ages 7 to 14 by zygosity, sex and being taught by the same or different (S/D) teachers

Age	S/D teacher		Zygoty*S/D		Zygoty*Sex		Sex, Zygoty*S/D	
	<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2
Age 7	.897	.000	.091	.001	.000	.005	.322	.001
Age 9	.018	.012	.874	.000	.026	.004	.171	.002
Age 10	.301	.000	.890	.000	.000	.013	.800	.001
Age 12	.033	.001	.482	.000	.000	.009	.094	.002
Age 14	.355	.000	.547	.000	.413	.002	.272	.002

One twin selected randomly. Bold indicates significance at $p \leq .05$. Results are from multiple tests.

Table 5. Motivation: ANOVA results of composite scores by zygosity, sex and by having the same or different (S/D) teachers

Age	Country	Motivation	S/D teacher		Zygosity*S/D		Zygosity*Sex		Sex, Zygosity*S/D	
			<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2
9	UK	English	.161	.001	.879	.000	.000	.016	.433	.002
		Mathematics	.387	.000	.740	.000	.000	.022	.842	.001
10	Quebec-	Reading	.524	.001	.819	.000	.591	.008	.271	.014
	Canada	Mathematics	.235	.004	.242	.004	.404	.011	.795	.005
12	Quebec-	Reading	.096	.008	.582	.001	.438	.011	.229	.016
	Canada	Mathematics	.007	.020	.458	.002	.363	.012	.465	.010
	UK	English	.003	.002	.830	.000	.000	.023	.437	.001
		Mathematics	.008	.002	.478	.000	.000	.007	.452	.001

One twin selected randomly. Bold indicates significance at $p < .05$.

Table 6. Absolute mean difference scores in achievement and motivation: ANOVA results between twin pairs taught by the same or different teachers by zygosity, sex and being taught by the same or different (S/D) teachers

Age	Country	Construct	School subject	S/D teacher		Zygosity*S/D		Zygosity*Sex		Sex, Zygosity*S/D	
				<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2	<i>p</i>	η^2
12	Quebec-Canada	Achievement	Composite	.008	.027	.403	.003	.000	.111	.540	.012
			Reading	.097	.008	.785	.000	.001	.054	.967	.002
		Motivation	Math	.114	.006	.506	.001	.000	.064	.715	.006
16	UK	Achievement	Math GCSE	.000	.036	.005	.005	.000	.042	.058	.006
			English GCSE	.000	.027	.464	.000	.000	.032	.726	.001

One twin selected randomly. Bold indicates significance at $p \leq .05$. Results are from multiple tests.

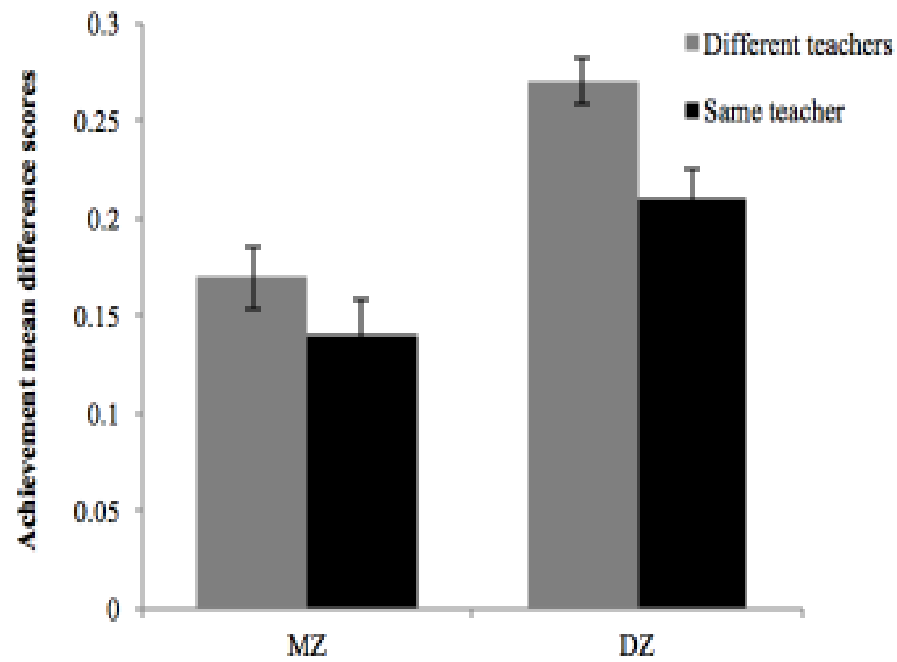


Figure 1. Absolute mean difference scores in academic achievement at age 12 for Quebec MZ and DZ twin pairs taught by the same or different teachers

* = Significant differences found at $p \leq .05$.

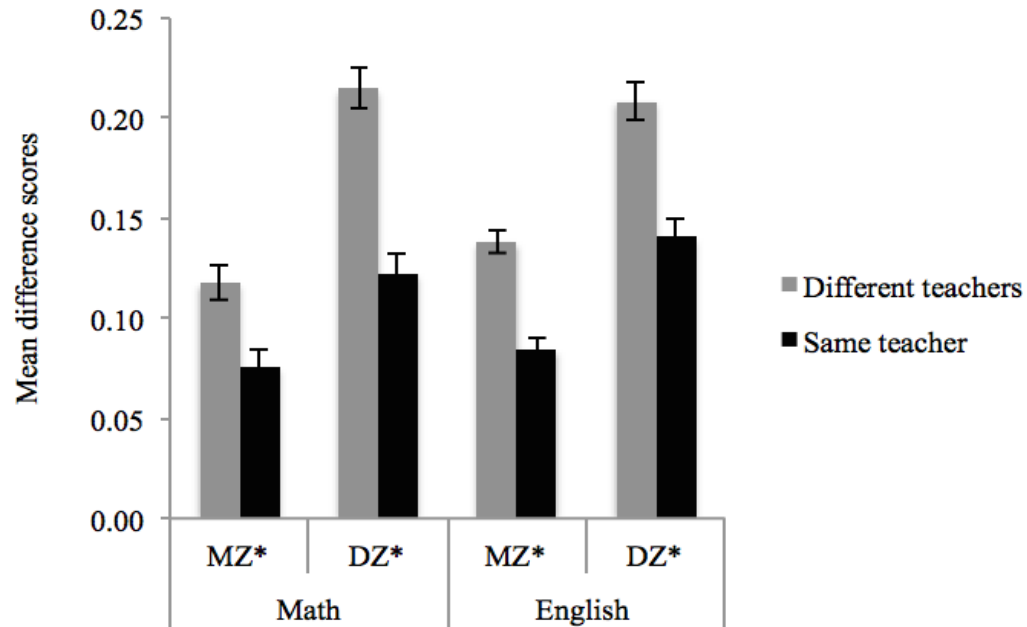


Figure 2. Absolute mean difference scores for GCSE grades in mathematics and English at age 16 for UK MZ and DZ twin pairs taught by the same or different teachers

* = Significant differences found at $p \leq .05$. Note: while larger within-pair differences found in math GCSE for separated DZ twin pairs, compared to separated MZ twins suggest the presence of a GxE interaction. However, we are unable to formally test this as the sub-sample of twin pairs with available same/different teacher data is too small for the analyses (less than 1000 twin pairs of each type, see Table 2c) (Plomin, DeFries, Knopik & Neiderhiser, 2013).

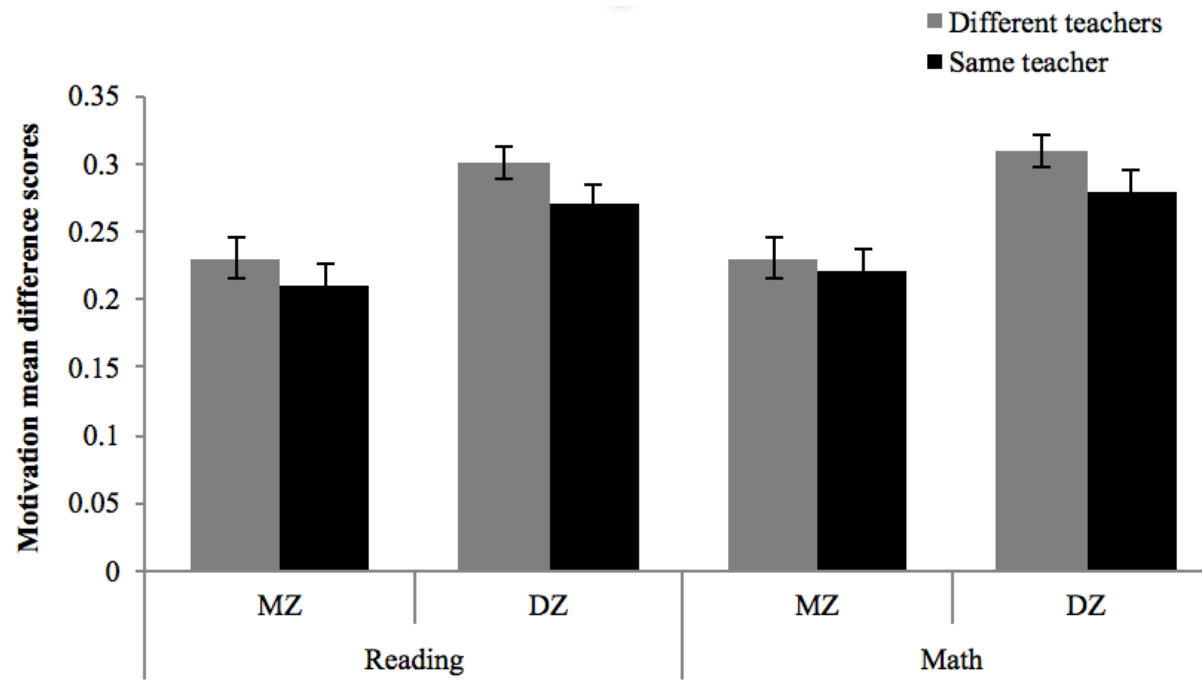


Figure 3. Absolute mean difference scores for motivation in reading and mathematics at age 12 for Quebec MZ and DZ twin pairs taught by the same or different teachers

* = Significant differences found at $p \leq .05$.