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Cultural capital, teacher bias, and educational success: New evidence from monozygotic twins

Mads Meier Jæger [a, *], Stine Møllegaard [b]

[a] Department of Sociology, University of Copenhagen, Øster Farimagsgade 5, 1353 Copenhagen K, Denmark
[b] Department of Sociology and Nuffield College, University of Oxford, Manor Road, Oxford OX1 3UQ, United Kingdom

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ABSTRACT

In this paper we use new data on Danish monozygotic (MZ) twins to analyze the effect of cultural capital on educational success. We report three main findings. First, cultural capital has a positive direct effect on the likelihood of completing the college-bound track in Danish secondary education. Second, cultural capital leads teachers to form upwardly biased perceptions of children's academic ability, but only when their exposure to children's cultural capital is brief (as in oral and written exams) rather than long (as in grades awarded at the end of the school year). Third, we find that the positive direct effect of cultural capital on educational success is higher for children from high-socioeconomic status (SES) backgrounds than for those from low-SES backgrounds. This result suggests that high-SES children are more likely to be in schooling contexts that enable them to convert cultural capital into educational success.

1. Introduction

Pierre Bourdieu's theory of cultural reproduction offers an influential explanation of why some children are more successful in the educational system than others. Bourdieu argued that cultural capital, that is familiarity with the dominant cultural codes in a society, is a key determinant of educational success because it is misperceived by teachers as academic brilliance and rewarded as such. Moreover, because children from high socioeconomic status (SES) backgrounds on average possess more cultural capital than those from low-SES backgrounds, they have a comparative advantage in the educational system which helps them reproduce their privileged social position (Bourdieu, 1977, 1984; Bourdieu and Passeron, 1990).

Despite widespread *prima facie* support for the theory of cultural reproduction (e.g., Aschaffenburg and Maas, 1997; Cheadle, 2008; de Graaf et al., 2000; DiMaggio, 1982; DiMaggio and Mohr, 1985; Dumais, 2002; Jæger, 2009; Roscigno and Ainsworth-Darnell, 1999; Sullivan, 2001; van de Werfhorst and Hofstede, 2007; Xu and Hampden-Thompson, 2012; Yamamoto and Brinton, 2010), empirical research that has sought to test this theory is limited in three important regards.

First, most research uses cross-sectional data and research designs that make it difficult to isolate the effect of individuals' cultural capital on educational success from the effect of other aspects of family background that are correlated with, but substantively different from, cultural capital (for example, economic and social capital). The consequence of this limitation is that existing research may overstate the effect of cultural capital because it conflates the effect of cultural capital with the

* Corresponding author.
E-mail addresses: mmj@soc.ku.dk (M.M. Jæger), stine.mollegaard@sociology.ox.ac.uk (S. Møllegaard).

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effect of other unmeasured aspects of family background that also affect educational success (Gaddis, 2013; Jæger, 2011; Kingston, 2001).

Second, most research estimates the effect of cultural capital on educational success but does not address the key mechanism through which Bourdieu argued that cultural capital operates: teacher bias. In Bourdieu's account, teachers misconceive cultural capital as academic brilliance, which leads to upwardly biased evaluations of children's academic ability. And although some research has analyzed the impact of cultural capital on teachers' evaluations of children (Bodovski and Farkas, 2008; Dumais, 2006; Farkas et al., 1990; Roscigno and Ainsworth-Darnell, 1999; Wildhagen, 2009), it has not systematically linked teacher bias to educational success.

Third, existing research has only to a limited degree analyzed heterogeneity in the effect of cultural capital on educational success (instead, it has focused on estimating the average effect of cultural capital). Some research suggests that the returns to cultural capital vary by family background because children from high- and low-SES backgrounds are in schooling contexts that vary with regard to how much they appreciate and reward cultural capital (Andersen and Jæger, 2015; Aschaffenburg and Maas, 1997; DiMaggio, 1982). However, only little research has explored this idea.

In this paper we use new data and a novel research design to address each of the three limitations outlined above. Our first contribution is that we use data on monozygotic (MZ) or identical twins from Denmark to estimate the effect of individual cultural capital on educational success. Since MZ twins are genetically identical at birth and are exposed to the same family environment during their upbringing, we are able to hold constant family background and isolate the causal direct effect of individual cultural capital on educational success (measured by Grade Point Average [GPA] at the end of compulsory school and the likelihood of completing upper secondary education, the college-bound track in Danish secondary education). Only three previous studies have addressed bias from unmeasured aspects of family background, for example by using sibling or panel data (Gaddis, 2013; Jæger, 2011; Jæger and Breen, 2016). We improve on this line of research by using an MZ twin design that controls fully for unmeasured genetic and environmental aspects of family background (e.g., Ashenfelter and Rouse, 1998; Guo and Stearns, 2002; Nielsen, 2006). Similarly with previous research that uses sibling data, our MZ twin design which controls for shared family background does not allow us to test Bourdieu's contention that cultural capital mediates the effect of family background on educational success. However, and as we explain in detail below, our design provides an important advantage over existing research by enabling us to plausibly estimate the causal *direct* effect of individual cultural capital on educational success (i.e., the effect which can be attributed to differences in cultural capital between individuals) and to identify heterogeneous returns to cultural capital (because our design controls for selection into different schooling contexts).

Our second contribution is that we test if the effect of individual cultural capital on educational success operates via teacher bias, as suggested by Bourdieu. We use information on two sets of GPAs for each twin in our data: (1) GPA based on grades awarded by teachers during the final year of compulsory school (at age 15/16) and (2) GPA awarded by anonymous reviewers and teachers in the final exams taken at the end of compulsory school. The key difference between the two GPAs (which are based on grades in the same subjects) is that the first is more likely to be influenced by cultural capital than the second. Teachers are exposed to a child's cultural capital throughout the school year which, according to Bourdieu, should affect their perceptions of the child's academic ability and their grading practices. By contrast, grades in the final exams are awarded jointly by anonymous reviewers (who never meet the child or, in the case of oral exams, only meet the child briefly) and by teachers (who do meet the child), which leaves much less room for cultural capital to operate. We assess the role of teacher bias by analyzing if the effect of cultural capital differs between the two sets of GPAs for the same child, with the hypothesis being that cultural capital should have a stronger effect on GPA awarded by teachers during the school year than on GPA awarded in the final exams.

Our third contribution is that we test if returns to cultural capital with regard to educational success vary by children's socioeconomic background. Existing research has proposed, but has been unable to convincingly distinguish, two competing hypotheses regarding heterogeneity in returns to cultural capital. The *cultural mobility hypothesis* argues that children from low-SES backgrounds have a higher return to cultural capital than those from high-SES backgrounds because they tend to be in schooling contexts with less cultural capital and, if possessed, cultural capital is easier to "show off" to one's advantage. By contrast, the *cultural reproduction hypothesis* argues that returns to cultural capital are higher for high-SES children because the schooling contexts that these children occupy are particularly susceptible to recognizing and rewarding cultural capital (de Graaf et al., 2000; DiMaggio, 1982; Jæger, 2011; Roscigno and Ainsworth-Darnell, 1999). Our research design is well-suited for distinguishing these two hypotheses because it controls for unmeasured aspects of family background that select high- and low-SES children into different schooling contexts. Thus, we can interpret SES gradients in returns to cultural capital as originating from differences between schooling contexts rather than from differences between families.

We report three main findings. First, we find that individual cultural capital has a positive direct effect on the likelihood of completing upper secondary education. The effect is substantively large even though there is only little variation between MZ twins with regard to how much cultural capital they possess. Second, and contrary to expectations, we find that individual cultural capital has a positive effect on GPA in the final exams at the end of compulsory school but has no effect on GPA awarded during the school year. This result suggests that cultural capital leads teachers to form biased perceptions of children's academic ability, but only when their exposure to children's cultural capital is brief, as is the case in a written or oral exam. Third, we find that the positive direct effect of individual cultural capital on educational success exists only among the children of the highly educated; children whose parents have low education reap no returns to their cultural capital. This result is consistent with the cultural reproduction hypothesis.

2. Theoretical background

This section presents our theoretical framework. We begin by introducing the concept of cultural capital and discussing its role for educational success, including different channels though which cultural capital may promote educational success. We then discuss different approaches to measuring cultural capital, describe the Danish context in which our research is situated, and present a set of hypotheses to be tested in the empirical analysis.

2.1. The concept of cultural capital

Bourdieu (1977, 1984, 1986) defined cultural capital as familiarity with the dominant cultural codes inscribed in a society. He argued that cultural capital is a resource which is equivalent to economic resources (referred to as *economic capital*) and social networks (referred to as *social capital*). In addition to being a resource in its own right, cultural capital can be converted into economic and social capital. Based on Bourdieu, Lamont and Lareau (1988: 156) define cultural capital, and its function, as "(…) institutionalized, i.e., widely shared, high status cultural signals (attitudes, preferences, formal knowledge, behaviors, goals, and credentials) used for social and cultural exclusion." This definition highlights that cultural capital can be invested to create more (or other types of) capital and fundamentally serves to exclude others from advantaged social positions. As explained below, cultural capital serves exactly this role in the educational system.

2.2. Cultural capital and educational success

According to Bourdieu, cultural capital exists in three states: *embodied* (language, mannerisms, preferences, etc.), *objectified* (cultural goods, books, works of art etc.), and *institutionalized* (educational credentials) (Bourdieu, 1977, 1986; Bourdieu and Passeron, 1990). It may promote social reproduction in all three states.

Parents transmit their cultural capital to children, either by unknowingly exposing them to objectified and embodied cultural capital in the home or by actively investing in transmitting their cultural capital to children (Cheung and Andersen, 2003; Jæger and Breen, 2016; Lareau and Weininger, 2004; Kraaykamp and van Eijck, 2010; Lareau, 2003). Over time children internalize parents' cultural capital, which becomes an integral part of their endowments and behaviors, i.e., what Bourdieu labels their *habitus*. Children may also acquire cultural capital outside the family, for example via peers or schools (Bisin and Verdier, 2011; Kisida et al., 2014).

Children exploit their cultural capital in the educational system. Bourdieu argues that cultural capital is particularly valuable within the field of education (Bourdieu, 1977, 1986; Bourdieu and Passeron, 1990) because this field valorizes cultural capital and ascribes positive qualities, for example academic brilliance, onto those who possess it. Children who possess cultural capital are familiar with the informal codes and systems of valorization in the educational system and, unlike those who do not possess cultural capital they are able to present a seemingly "natural" impression of academic brilliance. This impression is rewarded by teachers, for example via higher grades or placement in a more prestigious track. Thus, according to Bourdieu cultural capital has no intrinsic value and needs a "catalyst" (the teacher) to be converted into something useful.

2.3. Differential returns to cultural capital

It may be that, even if possessed, children differ in their ability to convert cultural capital into educational success. In particular, it may be that children from low-SES backgrounds benefit less from their cultural capital than children from high-SES backgrounds because they tend to be in schooling contexts that are less inclined towards recognizing and valorizing cultural capital. For example, high-SES children may be in schooling contexts in which the teaching style, curriculum, and school organization is particularly suited for converting cultural capital into educational success. This *cultural reproduction* hypothesis, which is consistent with Bourdieu's theory of cultural reproduction, suggests that returns to cultural capital are higher for high-SES children than for low-SES children. In an alternative explanation, called the *cultural mobility* hypothesis, DiMaggio (1982) proposed that returns to cultural capital is higher for low-SES children than for high-SES ones because, if possessed, low-SES children face less competition to "show off" cultural capital in the schooling contexts that they inhabit (Andersen and Jæger, 2015; de Graaf et al., 2000). We distinguish these two scenarios in the empirical analysis by analyzing if the effect of cultural capital on educational success varies by children's socioeconomic background.

We have now outlined the key ideas in the theory of cultural reproduction. We proceed by presenting different approaches to measuring cultural capital, our Danish context, and the hypotheses that we wish to test in the empirical analysis.

2.4. How to measure cultural capital

Empirical research has identified and measured four aspects of cultural capital. These aspects include (1) *familiarity with legitimate culture* (measured by, for example, how often parents or children participate in highbrow cultural activities; e.g., Aschaffenburg and Maas, 1997; DiMaggio, 1982; Katsillis and Rubinson, 1990; Roscigno and Ainsworth-Darnell, 1999), (2) *reading and literary interests* (measured by, for example, how many books children have and how often they read; e.g., de Graaf et al., 2000; Gaddis, 2013; Sullivan, 2001), (3) *extracurricular activities* (measured by, for example, participation in arts classes and academic clubs; e.g., Covay and Carbonaro, 2010; Kaufman and Gabler, 2004; Lareau, 2003), and (4) *cultural*

communication (measured by, for example, how often parents discuss cultural and social issues with children; e.g., Georg, 2004; Lee and Bowen, 2006; Tramonte and Willms, 2010). As explained below, in this paper we construct a summary scale that captures all four aspects of cultural capital.

2.5. The Danish context

Denmark is our institutional context. Here, children begin school around age six and are required by law to complete nine years of compulsory school (grades 1–9). The vast majority of children (more than 80 percent) attend public schools, which are funded and run by local municipalities. There is no tracking anywhere in compulsory school. Moreover, although there is no fixed national curriculum schools must cover the same general topics in each grade and must provide the same number of classes (for example, in math, English, and science). Almost all teachers have the same educational background (degree from a public Teacher College). At the end of compulsory school, at around age 15/16, children take final exams in all mandatory subjects (Danish, math, English, and science) and either proceed to secondary education or leave the educational system.

Secondary education in Denmark consists of an academic and a vocational track. The academic track, upper secondary education, takes three years and is similar to high school in the U.S., A levels in the United Kingdom and Abitur in Germany. The curriculum is academically oriented (for example, subject includes foreign languages, classical studies, and science), and upper secondary education is a formal requirement for admission to higher education.[1] Vocational education (for example, car mechanic and hairdresser) takes three to four years and combines school-based training with an apprenticeship position with an employer. Vocational education does not provide access to higher education, and this institutional aspect of Danish secondary education means that we would expect cultural capital to have a considerable effect on the decision about whether or not to enroll in upper secondary education.

2.6. Hypotheses

The first hypothesis that we wish to test is that individual cultural capital has a positive direct effect on educational success. Specifically, we expect that, compared to those who possess less cultural capital, children who possess more cultural capital have a higher GPA at the end of compulsory school (they present an impression of academic brilliance which is rewarded by teachers and which leads to higher grades) and a higher likelihood of completing upper secondary education (they choose the educational track that enables them to access higher education and, in the long run, an advantaged socioeconomic position).

The second hypothesis is that the effect of cultural capital operates via teacher bias. We observe two GPAs for each child: that comprised of grades awarded by teachers during the final year of compulsory school and that comprised of grades awarded by anonymous reviewers and teachers in the final exams. We hypothesize that if cultural capital operates via teacher bias, we expect it to have a stronger effect on GPA awarded during the school year than on GPA awarded in the final exams. Unlike teachers who are exposed to a child's cultural capital throughout the school year, the anonymous reviewers never meet the child (or, in the case of an oral exam, only meet the child briefly). In addition to overall exam GPA, our data also include information on each child's grade in oral and written Danish in the final exams. We use these two grades, which pertain to the same subject but to two different types of exams, to provide a supplementary test of teacher bias. Specifically, we hypothesize that if cultural capital operates via teacher bias we expect it to have a stronger effect on the oral grade than on the written grade because in the oral exam the child has the ability to physically "show off" her embodied cultural capital.

The third hypothesis is that returns to cultural capital vary by children's SES background. We test the two competing hypotheses presented above: *cultural reproduction* (the returns to cultural capital are higher for high-SES children than for low-SES children) and *cultural mobility* (the returns are higher for low-SES children than for high-SES children). Given the lack of clear results in previous research we do not have any a priori expectation about which hypothesis is more plausible.

3. Data and variables

We combine data from two sources: Danish administrative registers and a survey carried out among mothers of twins. Table 1 summarizes descriptive statistics for all variables included in the analysis for three groups: (1) all Danish children in the 1985–2000 birth cohorts (and their siblings), (2) all participants in the Mother of Twins Survey (twins and non-twin siblings, see below), and (3) MZ twins in the Mother of Twins Survey.

3.1. Administrative register data

Information on educational success and family background comes from Danish administrative registers. These registers cover the entire Danish population (approximately 5.6 million individuals) and include individual-level information on,

[1] Students' GPA at the end of upper secondary education is the single most important factor in determining post-secondary educational options. Although higher education is free in Denmark, almost all university programs have a minimum GPA that is required for admission. For prestigious program such as medicine and psychology, students must typically be in the top five percent of the GPA distribution to be admitted.

Table 1
Summary statistics. Means, standard deviations, and number of observations.

	1985–2000 cohorts*			Total DMTS Sample**			MZ Sample		
	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*
Educational outcomes									
Upper secondary education	0.23	0.42	1,410,671	0.24	0.43	13,897	0.26	0.44	4105
GPA (exam)	0.00	1.00	656,521	0.14	0.96	8553	0.15	0.96	2897
GPA (TAG)	0.00	1.00	646,544	0.09	0.98	8481	0.08	0.99	2875
Danish oral grade (exam)	0.00	1.00	647,936	0.09	0.98	8469	0.12	0.97	2875
Danish written grade (exam)	0.00	1.00	656,566	0.16	0.96	8555	0.18	0.95	2896
Cultural capital									
Cultural capital scale							0	1	2437
Control variables									
Sex (female)	0.49	0.50	1,474,252	0.49	0.50	14,032	0.50	0.50	4107
Age	20.70	7.50	1,474,252	20.35	5.50	14,032	20.07	4.09	4107
Birth weight (kilogram)	3.46	0.59	1,345,534	2.88	0.71	13,261	2.52	0.54	3897
Mother's education	2.77	1.22	1,263,350	2.89	1.18	13,118	2.90	1.17	3878
Father's education	2.66	1.26	1,151,404	2.74	1.26	12,209	2.73	1.24	3648
Mother's income	247.61	205.89	987,441	280.61	138.34	10,395	290.21	134.42	3114
Father's income	367.03	349.66	943,836	419.38	390.80	9990	415.18	301.58	2999
Single-parent family	0.36	0.48	1,116,769	0.27	0.44	12,199	0.26	0.44	3705
Non-Danish background	0.12	0.32	1,472,088	0.05	0.22	14,028	0.04	0.20	4107
Mother self-employed	0.05	0.21	1,013,178	0.05	0.22	10,408	0.05	0.22	3114
Father self-employed	0.11	0.31	981,608	0.11	0.31	10,254	0.10	0.29	3075

Note: TAG = Teacher-awarded Grade, * Cohort members and their siblings, ** Twins and siblings.

among other things, education, income, and health care usage. Individuals can be linked to other family members such as parents, siblings, and children. A key advantage of the register data is that they are of very high quality. Of particular relevance in this paper is the fact that there is practically no missing information on GPA, completion of secondary education, and family background. Moreover, because the data are collected, cross-checked, and used in everyday life by many public agencies, there is a low incidence of coding errors. The relevant population in this paper includes all twins born in the years 1985–2000. We sample these cohorts because they are the first for whom the Danish registers include information on GPA at the end of compulsory school.

3.2. Survey data

Our empirical design is based on comparing monozygotic (MZ) twin pairs. We identify twins via the administrative registers and define these as children born to the same mother on the same day. Using this definition, we identify 19,172 same-sex twins, corresponding to approximately 1.8 percent of all individuals in the 1985–2000 birth cohorts. The administrative registers do not include information on zygosity, and we add this information from a separate data source, the Danish Mother of Twins Survey (DMTS). The DMTS, which was carried out in 2013, consists of two parts: (1) a short telephone interview which targeted mothers of all same-sex twins in the 1985–2000 birth cohorts and which was designed to determine zygosity and (2) a follow-up web survey which included information on, among other things, cultural capital. The DMTS sampled same-sex twins because the objective of this survey was to maximize the sample of MZ twins.[2]

The telephone interview included a standardized battery of questions designed to determine if the twin pair is MZ or dizygotic (DZ). Research shows that this method of determining zygosity has an estimated accuracy of at least 93 percent when twins themselves are asked and between 87 and 97 percent when parents are asked (Rietveld et al., 2000). The reliability of the zygosity information in the DMTS is estimated to be 91.9 percent.[3] The response rate in the telephone survey was 72 percent.

Upon completion of the telephone interview, mothers of twins were invited to complete a follow-up web survey that included additional questions. The response rate in the web survey was 51 percent. In the web survey mothers provided information on each twin in the family and, where applicable, also on one older and one younger biological sibling (in total mothers provided information on up to four children: the twins and two additional children. We know from the registers that only 0.7 percent of mothers have more than four children, so the DMTS includes practically all children in the families under study). The web survey included questions on cultural capital and other aspects of the family environment.

[2] MZ twins always have the same sex, and by restricting the twin sample to same-sex twins the DMTS disregards twin pairs that cannot be MZ. Among same-sex twin pairs, approximately half are MZ and half are dizygotic (NCHS, 1992).

[3] We calculated this reliability using a sample of mothers in the DMTS who reported that the zygosity of their twins had been determined via DNA analysis. The reliability is calculated as the correlation between zygosity determined via the battery of questions intended to capture zygosity and zygosity determined via DNA analysis (the latter assumed to be 100 percent correct).

3.3. Dependent variables

We analyze two dimensions of educational success: GPA at the end of compulsory school (at around age 15/16) and a dummy variable indicating completion of upper secondary education (typically around age 18–19). All dependent variables are based on register data.

GPA is based on individual grades in the following mandatory written subjects: Danish, math, English, and science. Our measure of GPA is the mean grade across all subjects. Moreover, we observe two sets of GPA for each child: GPA based on grades awarded by teachers during the final year of compulsory school and GPA based on grades awarded in the final exams at the end of compulsory school.[4] The two measures of GPAs are closely spaced in time since the teacher-awarded grades are submitted just before the beginning of the final exams. Both GPA variables are standardized to have mean 0 and standard deviation 1. Moreover, we include variables measuring each child's standardized exam grade in oral and written Danish, respectively (Danish is the only subject for which students always attend both an oral and a written exam). In the empirical analyses we restrict the analytical samples to respondents age 15 and older for GPA (all measures) and age 17 and older for completion of upper secondary education.

3.4. Cultural capital

The DMTS web survey includes twelve indicators intended to capture the four different aspects of cultural capital described above (familiarity with legitimate culture, reading and literary interests, extracurricular activities, and cultural communication). Table A1 provides detailed information on each cultural capital indicator, including question wording and the estimated intraclass (i.e., within-MZ-twin-pair) correlation for each indicator (ICC).

The DMTS was designed such that mothers provided separate responses for each child in the family, i.e., a response for each twin and additional siblings, if any. Mothers were asked: “Here are a number of questions concerning your children's interests and habits. When you respond, please think about what each child was like when he or she was 12 years old.” We use the twelve items in the DMTS to construct a scale that measures individual cultural capital. This scale was constructed by means of a Principal Component Analysis (PCA) in which we hypothesize that mothers' responses on the twelve cultural capital indicators reflect a latent variable that captures each child's cultural capital. Table A1 shows the factor loadings for each of the twelve items included in the PCA (i.e., the weight with which each item contributes to the latent variable). The latent variable accounts for 31.3 percent of the total covariance between the twelve indicators, and we use predicted individual scores from the PCA as our indicator of cultural capital. As with GPA, we standardize the cultural capital scale to have mean 0 and standard deviation of 1.

Table A1 shows that the ICC for the individual items in the cultural capital scale is generally very high, in particular for the items capturing reading interests and cultural communication. This means that MZ twins differ little with regard to how much cultural capital they possess and, moreover, most of the variation in the cultural capital scale within MZ twin pairs comes from the items that capture cultural participation and extracurricular activities. We interpret the empirical results presented below in light of these facts, and in the appendix we provide an in-depth discussion of the validity of our cultural capital scale, including potential bias in mothers' responses arising from random measurement error, social desirability, and retrospective reporting.

3.5. Control variables

We also include several individual-level and family-background variables, all of which are based on the register data. The individual-level variables include gender (coded 1 for women and 0 for men), age in years, and birth weight (in kilograms). The family-background variables include father and mother's highest level of education (coded into 1997 ISCED categories where 1 = Compulsory school, 2 = Vocational education, 3 = Upper secondary education, 4 = Lower tertiary education (1–2 year vocationally oriented degree), 5 = Higher tertiary education (Bachelor and Master's Degrees), and 6 = PhD), father and mother's personal income before tax in thousands of Danish Kroner when the child was 15 years old, a dummy for non-Danish (i.e., immigrant) background, a dummy variable for living in a single-parent household at age 15, and dummies for whether the mother and father were self-employed.

4. Empirical design

This section presents our empirical design. The analysis has three interlinked objectives: (1) to estimate the causal direct effect of cultural capital on educational success, (2) to analyze the extent to which cultural capital operates via teacher bias, and (3) to analyze differences in returns to cultural capital for children from respectively high- and low-SES families.

The first objective is to estimate the direct effect of individual cultural capital on educational success. We illustrate the empirical design using the following linear regression model:

[4] The correlation between the two GPAs is 0.87 both in the total population (all children in the 1985–2000 birth cohorts) and among MZ twins.

$$y_{ij} = \alpha + c_{ij}\beta_1 + \mathbf{x}_{ij}\beta_2 + \mathbf{z}_j\beta_3 + f_j + \varepsilon_{ij}. \quad (1)$$

In this model y_{ij} is one of our indicators of educational success for child i ($i = 1, \ldots, N$) in family j ($j = 1, \ldots, J$). The model includes three types of explanatory variables (where letters in bold represent vectors of variables): individual cultural capital (c), individual-level controls ($\mathbf{x}$) and family background controls ($\mathbf{z}$). The c and $\mathbf{x}$ variables vary across children from the same family (hence subscript i), while the $\mathbf{z}$ variables do not. The model also includes a time-invariant, family-specific effect (f_j) which captures the influence of unmeasured aspects of family background (genetic and environmental) and a random error term (ε_{ij}).

Our objective is to estimate β_1, i.e., the effect of individual cultural capital on educational success. A causal interpretation of β_1 rests on the assumption that all relevant aspects of family background that are correlated with cultural capital and educational success are properly controlled in the $\mathbf{x}$ and $\mathbf{z}$ vectors. This assumption is rarely justified in cross-sectional research. In this paper we use an MZ twin design to control for f_j. To do this, we rearrange equation (1) into a "within-twin pair" fixed effect model:

$$\left(y_{ij} - \overline{y}_j\right) = (c_{ij} - \overline{c}_j)\beta_{1,MZ} + (\mathbf{x}_{ij} - \overline{\mathbf{x}}_j)\beta_{2,MZ} + (\mathbf{z}_j - \overline{\mathbf{z}}_j)\beta_{3,MZ} + \left(f_j - \overline{f}_j\right) + (\varepsilon_{ij} - \overline{\varepsilon}_j) \rightarrow$$
$$\left(y_{ij} - \overline{y}_j\right) = (c_{ij} - \overline{c}_j)\beta_{1,MZ} + (\mathbf{x}_{ij} - \overline{\mathbf{x}}_j)\beta_{2,MZ} + (\varepsilon_{ij} - \overline{\varepsilon}_j),$$

which can be expressed more compactly using a difference operator:

$$\Delta y_{ij} = \Delta c_{ij}\beta_{1,MZ} + \Delta \mathbf{x}_{ij}\beta_{2,MZ} + \Delta\varepsilon_{ij,MZ}. \quad (2)$$

This model, which we refer to as the "MZ model," relies on variation in cultural capital and educational success within MZ twin pairs to control out f_j. The benefit of the MZ twin design is that, unlike a sibling (or DZ twin) design, it controls fully for shared genetic and environmental aspects of family background that are correlated with cultural capital and educational success.[5]. As a consequence, the MZ twin design provides a stronger basis for a causal interpretation of β_1 than previous research.

We should clarify how $\beta_{1,MZ}$ should be interpreted and how it relates to previous research. Equation (2) shows that $\beta_{1,MZ}$ is identified from individual differences in MZ twins' cultural capital, i.e., it is net of all family background characteristics that MZ twins share (similarly, Jæger, 2011 estimates the effect of cultural capital net of all family background characteristics that siblings share). It is for this reason that we interpret $\beta_{1,MZ}$ as the causal *direct* effect of individual cultural capital on educational success (rather than as an *indirect* effect through which family background affects educational success). The consequence of the MZ design is that we cannot test Bourdieu's argument that cultural capital mediates the effect of family background on educational success (i.e., the causal chain: parents' cultural capital → children's cultural capital → children's educational success). Some previous research has addressed the extent to which cultural capital mediates the effect of family background on educational success (de Graaf et al., 2000; DiMaggio, 1982; Roksa and Potter, 2011), but this research is based on cross-sectional data and is vulnerable to bias from unmeasured aspects of family background (captured in f_j).[6] By contrast, the MZ twin design identifies a narrower effect of individual cultural capital on educational success (children's cultural capital → children's educational success), but also an effect which has a clearer interpretation and, under known assumptions (which we discuss in the appendix), a causal interpretation.

In the second step of the empirical analysis we analyze if the causal direct effect of individual cultural capital on educational success operates via teacher bias, as argued by Bourdieu. We test this hypothesis by estimating the MZ model using the two different measures of GPA in our data as dependent variables (GPA awarded during the final year of compulsory school and GPA awarded in the final exams). As a supplementary analysis, we also use individual grades in oral and written Danish in the final exams as dependent variables.

In the third step we analyze if returns to cultural capital are different in high- and low-SES families. This analysis enables us to distinguish the cultural reproduction and cultural mobility hypotheses described earlier. Our MZ twin design controls for unmeasured aspects of family background that select families and children into different schooling contexts. Consequently,

[5] Bourdieu treats cultural capital as originating solely from environmental influences. However, there is evidence that some traits which are linked to cultural capital, for example language acquisition, preferences, and reading skills, are partly shaped by genes passed on from parents to children (Christopher et al., 2013; Ebstein et al., 2010; McGue and Bouchard Jr. 1998).

[6] We think that it is difficult to imagine a research design which would allow us to empirically identify the entire causal chain in Bourdieu's theory of cultural reproduction (parents' cultural capital → children's cultural capital → children's educational success). Imagine that we could randomly assign cultural capital to parents. In that case we could identify the causal effect of parents' cultural capital on children's cultural capital (i.e., the intergenerational transmission of cultural capital) and, in a second step, the causal effect of children's cultural capital on their educational success (both net of f_j). Random assignment of cultural capital to children (for example via a randomized controlled trial, as in Kisida et al., 2014, or via a policy change as in Nagel et al., 2010) would allow us to identify the causal direct effect of children's individual cultural capital on their educational success (as we do in this paper), but not the intergenerational transmission of cultural capital which is central to Bourdieu's argument. Consequently, in the absence of random assignment of cultural capital to parents, we argue that it is not possible to jointly identify the intergenerational transmission of cultural capital and the effect of cultural capital on children's educational success.

any difference that we find between high- and low-SES children in the effect of individual cultural capital on educational success is likely to be due to contextual differences in the ways in which children convert cultural capital into educational success. For example, it may be that high-SES children are more likely to be in schooling contexts in which the teaching style, curriculum, and school organization is conducive to converting cultural capital into educational success. Operationally, we define two SES subgroups – high and low – based on parents' education and income. For parental education, we distinguish two SES groups: Parents who have completed higher education (lower and higher tertiary education; equivalent to two- and four-year college in the U.S.) and parents who have not completed higher education (i.e., parents who have compulsory school, upper secondary or vocational education as their highest level of education). These two groupings reasonably distinguish the high and low educated in Denmark. For parental income, we distinguish two subgroups: Parents whose total household income is above the mean in the MZ sample and parents whose household income is below the mean. These were the most detailed subgroups we could create while still retaining a reasonable sample size.

5. Results

We divide the presentation of the empirical results into three sections. First, we present estimates of the causal direct effect of cultural capital on educational success (GPA and completion of upper secondary education). Second, we analyze if the effect of cultural capital on GPA differs depending whether grades are awarded in exams or by teachers during the school year. Third, we analyze if returns to cultural capital are different for high- and low-SES children.

5.1. Cultural capital and educational success

We begin by analyzing the direct effect of individual cultural capital on educational success. Table 2 summarizes results from regressions of our three main indicators of educational success (exam GPA, teacher-awarded GPA, and completion of upper secondary education) and two supplementary indicators (Danish oral and written exam grade). We estimate two model specifications using the MZ sample: (1) cross-sectional Ordinary Least Squares (OLS) regressions (i.e., models similar to those estimated in previous research, cf. equations (1), and (2) twin-differenced models (cf. equation (2)).

Table 2 shows that in the baseline OLS model the scale capturing children's cultural capital has a statistically significant and positive effect on both measures of GPA but has no effect on the likelihood of completing upper secondary education. This baseline result suggests that cultural capital affects academic achievement (GPA) but has no direct effect on educational attainment (upper secondary education).

Table 2
Regressions of Educational Success on Cultural Capital. OLS and Twin-Differenced Models. MZ sample.

Educational outcomes	OLS					Twin FE				
	GPA (exam)	GPA (TAG)	Upsec. Edu.	Danish Oral G.	Danish Written G.	GPA (exam)	GPA (TAG)	Upsec. Edu.	Danish Oral G.	Danish Written G.
Cultural capital	0.143***	0.127***	0.013	0.139***	0.130***	0.301*	0.141	0.125*	0.288	0.208
	(0.036)	(0.027)	(0.012)	(0.036)	(0.032)	(0.132)	(0.141)	(0.056)	(0.182)	(0.138)
Sex (female)	0.193**	0.184**	0.131***	0.339***	0.457***					
	(0.060)	(0.063)	(0.027)	(0.070)	(0.052)					
Age	−0.012	−0.004	0.098***	−0.014	−0.006					
	(0.010)	(0.011)	(0.005)	(0.008)	(0.010)					
Birth weight (kilogram)	−0.029	−0.062	−0.029	−0.012	0.008	0.055	0.027	0.007	0.115	0.002
	(0.047)	(0.049)	(0.027)	(0.067)	(0.053)	(0.066)	(0.049)	(0.028)	(0.117)	(0.091)
Mother's education	0.106***	0.099***	0.039**	0.093***	0.062*					
	(0.027)	(0.028)	(0.013)	(0.023)	(0.030)					
Father's education	0.117***	0.113***	0.057***	0.070*	0.116***					
	(0.021)	(0.024)	(0.012)	(0.029)	(0.019)					
Mother's income	0.001*	0.001*	0.000	0.000*	0.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
Father's income	0.000	0.000	0.000	0.000	0.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
Single-parent family	−0.177**	−0.253***	−0.080	−0.133*	−0.136					
	(0.061)	(0.059)	(0.041)	(0.063)	(0.074)					
Non-Danish background	0.294***	0.942***	0.205***	0.632***	1.065***					
	(0.083)	(0.095)	(0.037)	(0.090)	(0.085)					
Mother self-employed	−0.018	−0.108	−0.032	−0.078	−0.002					
	(0.128)	(0.130)	(0.077)	(0.139)	(0.102)					
Father self-employed	0.215*	0.293***	0.032	0.186	0.108					
	(0.095)	(0.082)	(0.040)	(0.097)	(0.084)					
N	1460	1462	1386	1450	1448	1460	1462	1386	1450	1448

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, TAG = Teacher-awarded GPA. OLS models adjust standard errors for clustering of individuals within families. Models for GPA run for twins age 15 + and models for completion of upper secondary education run for twins age 17+.

Results from the MZ models, which control for a comprehensive range of unmeasured family background characteristics, provide a somewhat different impression. Here, we find that cultural capital has a statistically significant and positive effect on exam GPA but has no effect on teacher-awarded GPA. Moreover, unlike in the OLS model cultural capital has a statistically significant and positive effect on the likelihood of completing upper secondary education (we note that the estimate of β_1 from the MZ model is statistically significantly different from the estimate from the OLS model at $p < 0.05$). The direct positive effect of individual cultural capital on the likelihood of completing upper secondary education is of some magnitude: an increase in cultural capital of one standard deviation is estimated to increase the likelihood of completing upper secondary education by 12.5 percentage points. This result is in line with our first hypothesis that possessing more cultural capital has a positive effect on the likelihood of completing an educational degree that is necessary for long-term educational success. We may benchmark the substantive effect of cultural capital relative to other aspects of family background whose effects are summarized in the OLS model. For example, an increase in father's education of one unit (on a 1–6 scale) is estimated to increase the probability of completing upper secondary education by 5.7 percentage points. Also, the direct effect of cultural capital in the MZ model is almost similar to the gender difference in the likelihood of completing upper secondary education (13.1 percentage points), as is also reported in Table 2.

The positive effect of cultural capital that we find in the MZ model should be interpreted in light of our research design and empirical measurement of cultural capital. First, in the MZ model we use only a small share of the total variance in cultural capital. This fact is evident in the larger standard error associated with the coefficient on cultural capital. Second, the positive effect of cultural capital must be interpreted in light of where the variation in MZ twins' cultural capital comes from. As we explained above, the cultural capital indicators along which MZ twins differ the most are the ones that capture cultural participation and extracurricular activities. This means that the direct positive effect of individual cultural capital on the likelihood of completing upper secondary education arises principally from differences between MZ twins in these dimensions. Recent research on cultural capital argues that extracurricular activities may enhance children's intellectual creativity, breadth, and scope (Kaufman and Gabler, 2004) and moreover that cultural participation may lead to a genuine increase in analytical and academic competence (Kisida et al., 2014). If these arguments are true, the positive effect of individual cultural capital that we find may arise in part from skills learned via cultural participation and extracurricular activities, which are valuable in the educational system and which promote educational success.[7]

5.2. Cultural capital and teacher bias

Having provided evidence that individuals who possess more cultural capital have a higher likelihood of completing upper secondary education, we now turn to the second hypothesis which pertains to the mechanisms through which cultural capital operates. Following Bourdieu, we hypothesized that if cultural capital operates via teacher bias we expect it to have a stronger effect on GPA awarded during the school year than on GPA awarded in the final exams. Table 2 shows that in the MZ models cultural capital has a positive direct effect on GPA awarded in the final exams but has no effect on GPA awarded during the school year (both coefficients are positive but are not statistically significantly different). This result contradicts our hypothesis that prolonged exposure to cultural capital affects teachers' perceptions of children's academic ability, which in turn affects their grading practices. An alternative explanation of this finding is that teachers who are exposed to a child's cultural capital throughout the school year are able to "see through" her cultural capital and assess her true academic ability. Exam grades are different because they depend to a considerable extent on the assessment of an anonymous reviewer who never meets the child (or, in the case of an oral exam, who only meets the child for a short period of time). It may then be that cultural capital only affects teacher perceptions when it is applied to "strangers" who do not have a priori information about the child's academic ability. Overall, our results provide some, but not very strong empirical evidence in favor of the hypothesis that cultural capital operates via teacher bias. This conclusion is reinforced in supplementary analyses (also reported in Table 2) in which we analyze the effect of cultural capital on children's exam grade in oral and written Danish and where we expect cultural capital to have a stronger effect on the oral grade than on the written grade. The result reported in Table 2 show that although the coefficients on cultural capital are in the expected direction for both grades, none are statistically significant.

5.3. SES gradients in returns to cultural capital

The third hypothesis we test concerns heterogeneous returns to cultural capital. We analyze this question by running the MZ model in different subgroups defined by parental education and income (both observed when the child whose educational outcomes we analyze was 15 years old). Table 3 summarizes results.

The striking result from Table 3 is that the positive direct effect of individual cultural capital on the likelihood of completing upper secondary education that we observed in Table 2 exists only in families in which parents have high (college) education. Children of the highly educated have a high return to their cultural capital ($\beta_{1,MZ} = 0.238$, $p < 0.01$), while children

[7] We have also used PCA to create separate subscales for each of the four dimensions of cultural capital that our items capture and have included these separately in the MZ models. However, this approach was not feasible because there is insufficient variation in each subscale for us to reliably estimate its effect on educational success.

Table 3
Regressions of Educational Success on Cultural Capital, by Parental Education and Total Household Income. MZ sample.

Parents' highest education:	Low		High	
	Estimate	*N*	Estimate	*N*
Educational outcomes				
Upper secondary education[a]	−0.035	636	0.238**	750
	(0.081)		(0.083)	
Grades:				
GPA (exam)	0.188	660	0.375*	800
	(0.296)		(0.150)	
GPA (TAG)	0.149	660	0.136	802
	(0.227)		(0.133)	
Danish oral grade (exam)	0.197	650	0.347	800
	(0.216)		(0.208)	
Danish written grade (exam)	0.422	654	0.068	794
	(0.287)		(0.136)	
Parents' total household income	Below mean		Above mean	
	Estimate	*N*	Estimate	*N*
Educational outcomes				
Upper secondary education	0.169	844	0.064	542
	(0.099)		(0.044)	
Grades:				
GPA (exam)	0.331	862	0.244	598
	(0.180)		(0.173)	
GPA (TAG)	0.222	866	0.049	596
	(0.209)		(0.139)	
Danish oral grade (exam)	0.328	854	0.240	596
	(0.295)		(0.216)	
Danish written grade (exam)	0.384	852	0.022	596
	(0.216)		(0.175)	

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, TAG = Teacher-awarded GPA.
[a] Parameter estimate for low/high parental education and income statistically significantly different at $p < 0.05$.

of the low educated have no return ($\beta_{1,MZ} = -0.035$, $p > 0.05$). The coefficients on cultural capital in the high- and low-educated groups are statistically significantly different at $p < 0.05$. This result is consistent with Bourdieu's cultural reproduction hypothesis which suggests that children in high-SES families reap higher returns to cultural capital than children from low-SES families. Since our MZ models control for selection into different schooling contexts, we interpret the educational gradient in returns to cultural capital as arising from contextual differences in the ways in which children convert their cultural capital into educational success.[8] We argued earlier that cultural capital, and especially extracurricular and cultural activities, may enhance intellectual curiosity and academic competence (Kaufman and Gabler, 2004; Kisida et al., 2014). If this is the case, the positive direct effect of cultural capital among children of the highly educated may capture that these children are in schooling contexts that recognize and reward these types of skills. This interpretation is further supported by the finding also shown in Table 3 that the positive direct effect of individual cultural capital on exam GPA is statistically significant only for children whose parents are highly educated.

Table 3 shows that there is no statistically significant difference in returns to cultural capital for children whose parents have above- and below-mean income, respectively. This means that in the Danish context we observe heterogeneous returns to cultural capital across families with different educational qualifications, but not different income levels. We interpret this result in light of the fact that compared to other countries Denmark has a low level of income inequality but not an equally low level of educational inequality (Black and Devereaux, 2011). Consequently, it may be that in the Danish context (characterized by a high level of income redistribution, free education and extensive social benefits and services) parents' income is not a particularly important SES gradient. We discuss the implications of these findings in the final section.

5.4. Robustness tests

We have carried out a number of robustness tests to assess the external validity of our MZ design and the potential impact of bias in our indicators measuring cultural capital. We present results from these analyses in the appendix. The conclusions

[8] An alternative explanation might be that the SES gradient in returns to cultural capital is driven by SES differences in the extent to which parents reinforce or compensate initial ability differences between MZ twins (Ayalew, 2005; Frijters et al., 2010). If high-SES parents reinforce initial differences while low-SES parents diminish these differences, our results need not reflect the impact of differential schooling contexts but rather differential parenting practices. To test this conjecture, we have analyzed if similarities in cultural capital between MZ twins (captured by the ICC) differs across the distribution of parental education and income. We find no evidence that high-SES MZ twins are more (dis)similar with regard to cultural capital compared to low-SES twins. Moreover, our MZ models include twins' birth weight as an explanatory variable which, at least to some extent, accounts for initial ability differences.

are that (1) the main results from our MZ models are similar to those found when replicating the analysis on the entire population and that (2) bias from measurement error in our cultural capital variables most likely has only a modest impact on our substantive findings.

6. Discussion

This paper was motivated by what we regard as a discrepancy between the widespread belief in Bourdieu's theory of cultural reproduction and the lack of empirical support for key assumptions in this theory. Although previous research documents positive correlations between cultural capital and educational success, it has not yet provided compelling evidence that this relationship is causal or that cultural capital operates via teacher bias, as suggested by Bourdieu. This paper extends previous research by (1) using data on Danish monozygotic (MZ) twins to provide credible estimates of the causal direct effect of individual cultural capital on educational success, (2) analyzing the effect of individual cultural capital on two measures of academic achievement that differ in their susceptibility to cultural capital, and (3) analyzing socioeconomic gradients in returns to cultural capital.

The main empirical finding is that cultural capital has a positive and arguably causal direct effect on educational success. Compared to those who possess less cultural capital, children who possess more cultural capital have a higher likelihood of completing upper secondary education, the college-bound track in Danish secondary education. The second finding is that cultural capital manifests in teacher bias to some extent, but not in the way that we anticipated. Cultural capital has a positive effect on GPA awarded in exams but has no effect on GPA awarded during the school year. These findings contradict the idea that cultural capital would be more effective when it is applied to teachers whom a child encounters on a daily basis. We offer the alternative explanation that while a teacher who interacts with a child throughout the school year is able to "see though" the child's cultural capital, an anonymous reviewer who is exposed only briefly to a child (especially in an oral exam) and who lacks a priori information about the child is more easily swayed by her cultural capital. The third empirical finding is that cultural capital yields a positive return for children of highly educated parents but no yields return for children of low-educated parents. This result is consistent with the cultural reproduction hypothesis. Since our research design controls for selection into schooling contexts, we argue that the observed SES gradient in returns to cultural capital arises from differences across schooling contexts in their ability to enable children to convert their cultural capital (for example intellectual creativity and academic competence) into educational success. Unfortunately, our analysis is not informative about the ways in which schooling (or other social) contexts matter, and more research is needed to shed light on this issue.

Results from the present analysis feed into ongoing discussions about the role of cultural capital in shaping educational success. From a theoretical perspective our findings suggest that teacher bias exists but plays only a minor role in the overall impact of cultural capital on educational success. Instead, we suggest that the main mechanism through which cultural capital affects educational success is via skills or behaviors that are associated with cultural capital. For example, participation on cultural activities and extracurricular activities may foster skills in children such as creativity and academic competence that are beneficial in the educational system over and above pure academic ability. In this regard, the positive effect of cultural capital on educational success is not directly related to how teachers perceive children, but rather to what types of skills children possess and how different schooling contexts enable children to convert these skills into educational credentials (Calarco, 2011; Lareau, 2003).

We also find that high-SES children have higher returns to cultural capital than low-SES ones with regard to exam GPA and the likelihood of completing upper secondary education. This finding is striking, especially in the "standardized" Danish compulsory school system in which the absence of tracking and private schools would suggest that there should be only few SES gradients. Our research design compares MZ twins from the same family, so the reason why high-SES children have higher returns to cultural capital must lie outside the family of origin, for example in schooling or social contexts in which children fare.

Finally, we should highlight three limitations in our analysis and how we address them. First, like most other research that uses a twin design we use only a small proportion of the total variance in cultural capital and educational success in our data. This means that statistical power is low and that the external validity of the findings may be compromised. However, despite low statistical power we find statistically significant effects of cultural capital on educational success, and we address the external validity of the twin design in the appendix. Second, the MZ twin design means that we are unable to test Bourdieu's argument that cultural capital mediates the effect of cultural capital on educational success (family background → cultural capital → educational success). However, we argue that instead we identify the direct effect of *individual* cultural capital on educational success and, moreover, an effect which has a causal interpretation. Third, the indicators that we use to capture cultural capital do not contribute equally to creating the empirical variance in cultural capital between MZ twins and, moreover, the items are based on mothers' retrospective reports which may be biased. We interpret the effect of cultural capital on educational success in light of where the empirical variation in cultural capital comes from (cultural participation and extracurricular activities) and argue in the appendix that bias in mothers' reports of children's cultural capital most likely has only a modest impact on our findings. In spite of these empirical limitations, we believe that our analysis makes an important contribution by demonstrating that individual cultural capital affects educational success even in a highly egalitarian context, that cultural capital affects perceptions of academic ability – and grading practices – in some situations, and finally that the payoffs to possessing cultural capital have a distinct socioeconomic gradient.

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Appendix

A.1. Robustness tests

In this appendix we address two issues which might affect our findings: the external validity of the twin design and bias in mothers' reports of children's cultural capital.

A.2. External validity

Although the twin design has many advantages, there is an ongoing discussion about whether twin families are special and, as a consequence, whether results from twin-based research generalize to other populations. The twin design rests on what is known as the Equal Environments Assumption (EEA), which states that similarities in the co-twin environment must not be predictive of co-twin outcomes. Although it is well-known that MZ twins on average have more similar environments than DZ twins (and siblings in general), there is little evidence that this stronger similarity affects a wide range of co-twin outcomes (Conley et al., 2013; Felson, 2014). However, although we do not consider the EEA assumption to be a major concern we did carry out two sets of additional analyses to assess the external validity of our results.

First, we ran OLS regressions of our indicators of educational success (GPA and the likelihood of completing upper secondary education) on all the individual and family background variables listed in Table 1 both in the total population (i.e., everyone in the 1985–2000 birth cohorts) and in the sample of DMTS twin families. Results from these analyses (available upon request) show that the associations between family background (parental education, income, etc.) and educational success are practically identical among twin families and in the general population. Thus, there is no evidence that the twin families in the DMTS are special. There is some evidence of sample selection in the DMTS since, compared to the total population of twin families in the 1985–2000 birth cohorts, twin families in the DMTS have somewhat higher education and income. To address this issue we ran additional analyses in which we used available register information on the twin families that were sampled for, but did not participate in, the DMTS to construct sampling weights that adjust for non-random participation in the DMTS, and our main results did not change.

Second, we reran the main empirical analyses using information on non-twin siblings in the DMTS families to provide a more general approximation of the family fixed effect (f_j in equation (1)) than is possible with twins alone. The idea is that, instead of relying on twins alone (whose family environment may differ from that of regular siblings due to closer spacing), we use information on all siblings in the family (twin and non-twin) to provide a better approximation of the shared family environment. Specifically, we use DMTS families with MZ twins and an additional sibling to first estimate the overall family fixed effect shared by all children in the family and then add a second fixed effect to account for the extra similarity (genetic and environmental) between MZ twins. Table A2 shows estimates of the effect of cultural capital on educational success from these "within-family, twin-differenced" models and replicates estimates from the main twin-differenced models (from Table 2). The table shows that although significance levels differ slightly from those reported in Table 2 (sample sizes are lower since we omit DMTS families who have twins but not a third child), the overall pattern of effects is the same.

A.3. Bias in mothers' reports

We now address potential bias in mothers' reports of children's cultural capital arising from forgetfulness, social desirability, and recall.

Forgetfulness bias: In the DMTS mothers provide retrospective reports on children who were between 13 and 28 years old at the time of the survey (mean age is 20.4 years). This retrospective design may induce random measurement error in our indicators capturing cultural capital if forgetfulness leads mothers to provide inaccurate information on children's cultural activities in the past (de Vries and de Graaf, 2008; Khoury et al., 1994). Random measurement error leads to attenuation bias,

i.e., downwardly biased estimates of the effect of cultural capital on educational success. This is a particular concern in an MZ study that relies on only a small proportion of the total variance in cultural capital. We have no way of directly addressing random measurement error because we have only one observation of cultural capital for each child in the family. However, we note that we get statistically significant estimates of the effect of individual cultural capital on educational success even in the presence of attenuation bias. We also note that the MZ design controls for fixed differences between mothers with regard to their forgetfulness (via f_j), and this may be one explanation of why we get a statistically significant effect of cultural capital on educational success in the MZ model in Table 2 but an insignificant effect in the OLS model.

Social desirability bias: It may be that mothers in the DMTS underreport differences between MZ twins' cultural activities and behaviors because they think others find differential treatment of children socially unacceptable (King and Bruner, 2000). The consequence of social desirability bias is that mothers underreport factual differences between MZ twins' cultural capital, which leads to downwardly biased estimates of the effect of cultural capital on educational success. While we cannot directly address social desirability bias (this would require separate survey instruments), we note that there are no systematic differences in the similarity between MZ twins' cultural capital across the distribution of parental education and income (cf. end note 8). This result could be interpreted to suggest that, if it exists, social desirability does not have a socioeconomic gradient in our data.

Recall bias: Mothers' reports of children's cultural capital in the past may also be affected by information on children's outcomes in the present (for example, their academic or social development). If true, mothers' reports of children's cultural capital are likely to be biased because these reports reflect later outcomes that are correlated with children's educational success. Our MZ design relies exclusively on variation within families. Unlike in a cross-sectional design this means that it controls for differences in mothers' propensity to assign weight to later outcomes when reporting on children's cultural capital in the past. Still, we use DMTS families with DZ twins and an extra child to provide an indirect test of recall bias. In these families all siblings (twin and non-twin) share the same amount of family background (genetic and environmental). Consequently, from the perspective of a mother who reports retrospectively on her children's cultural capital at age 12, the only difference between the DZ twins and the older/younger sibling is age. It then follows that if recall bias affects mothers' reports, we expect reports of cultural capital among DZ twins (who are of identical age) to be more similar than reports of cultural capital among a DZ twin and the older/younger sibling in the family (who differ in terms of age). To test this idea, we first estimate the ICC in overall cultural capital between DZ twins, which is estimated to be 0.92. We then estimate the intraclass correlation (ICC) for a randomly selected DZ twin within a DZ family and the older/younger sibling from this family (the only difference between the two siblings being age), which is estimated to be 0.86. Consequently, there is some evidence that, within families, mothers report less consistently on cultural capital for children who are of different age. Nonetheless, we note that even though there is some evidence of recall bias, the difference in ICC is not very large and is unlikely to have any major impact on our results.

Table A1
Summary of Cultural Capital Indicators.

Aspect of cultural capital		Indicator	Response categories	ICC	FL
Familiarity with legitimate culture	1	How often child went to any type of museum	(1) Never, (2) Once or twice a year, (3) More than twice a year, (4) Once a month, and (5) Once a week or more	0.957	0.276
	2	How often child went to the theater or a musical performance	Same as previous	0.913	0.300
	3	How often child went to the cinema	Same as previous	0.968	0.253
Reading and literature interests	4	How many books child has (not shared with others)	(1) None, (2) 1–9, (3) 10–19, (4) 20–49, and (5) 50 or more	0.995	0.371
	5	How often child reads books and magazines for enjoyment (not homework/school assignment)	(1) Never, (2) Several times a year, (3) Several times a month, (4) Several times a week, and (5) Every day	0.994	0.338
	6	How often child went to the library to borrow books, comic books, or music	Same as previous	0.994	0.217
Extracurricular activities	7	Parents encouraged child to start and keep doing hobbies (not sports)	(0) No, (1) Yes	0.982	0.195
	8	Child likes to play a musical instrument	(0) No, (1) Yes	0.727	0.207
Cultural communication	9	How often mother discussed political or social issues with child	(1) Never, (2) Once or twice a year, (3) More than twice a year, (4) Once a month, and (5) Once a week or more often	0.987	0.339
	10	How often mother discussed books, movies, or television programs	Same as previous	0.996	0.360
	11	How often mother listened to classical music with child	Same as previous	0.994	0.339
	12	How often talked with child about how he/she was doing in school	Same as previous	0.991	0.178
Cultural capital scale				0.972	

Note: ICC = Intraclass correlation, FL = Factor loading.

Table A2
Regressions of Educational Success on Cultural Capital, Twin-Differenced and Within-Family, Twin-Differenced Models. MZ sample.

Educational outcome:	GPA (exam)	GPA (TAG)	Upsec. Edu.	Danish oral grade (exam)	Danish written grade (exam)
Twin-Differenced Model:					
Cultural capital	0.301*	0.141	0.125*	0.288	0.208
	(0.132)	(0.141)	(0.056)	(0.182)	(0.138)
N	1460	1462	1386	1450	1448
Within-Family, Twin-Differenced Model:					
Cultural capital	0.354*	0.156	0.089	0.362*	0.164
	(0.166)	(0.150)	(0.062)	(0.185)	(0.156)
N	1092	1094	1026	1082	1080

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, TAG = Teacher-awarded GPA.

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