Intelligence 92 (2022) 101642

Contents lists available at ScienceDirect

Intelligence

journal homepage: www.elsevier.com/locate/intell

Not by *g* alone: The benefits of a college education among individuals with low levels of general cognitive ability

Matt McGue [*], Elise L. Anderson, Emily Willoughby, Alexandros Giannelis, William G. Iacono, James J. Lee

Department of Psychology, University of Minnesota, United States of America

ARTICLE INFO

Keywords:
Low-average IQ
Returns to college
Non-ability contributors to educational attainment
General cognitive ability

ABSTRACT

In a longitudinal sample of 2593 individuals from Minnesota, we investigated whether individuals with IQs $\leq$ 90 who completed college experienced the same social and economic benefits higher-IQ college graduates did. Although most individuals with IQs $\leq$ 90 did not have a college degree, the rate at which they completed college had increased approximately 6-fold in men and 10-fold in women relative to rates in the previous generation. The magnitude of the college effect on occupational status, income, financial independence, and law abidingness was independent of IQ level, a finding replicated using the nationally representative NLSY97 sample. Additional analyses suggested the association of college with occupational status was consistent with a causal effect and that the educational success of individuals with low-average IQs may depend in part on non-ability factors, family socioeconomic status and genetic endowment. We discuss our finding in the context of the recent expansion in college attainment as well as the dearth of research on individuals with low-average IQs.

1. The impact of general cognitive ability on social achievements

General cognitive ability (GCA, or often simply *g*) is one of psychology's most powerful individual differences traits, its significance deriving principally from the broad array of academic, social, and economic outcomes with which it has been linked (Warne, 2020). GCA is moderately to strongly correlated with occupational and educational attainment, income, job performance, health, and economic independence (Deary & Batty, 2007; Fors, Torssander, & Almquist, 2018; Herrnstein & Murray, 1994; Kuncel, Hezlett, & Ones, 2004; Strenze, 2007). The observation that many of these associations also hold prospectively (Fergusson, Horwood, & Ridder, 2005) has led to the conclusion that GCA is not merely predictive but rather causally impacts the many important life outcomes with which it has been linked (Gottfredson, 1997).

Although the strongest support for the impact of GCA on diverse social outcomes has come from surveys of large representative samples, support is also seen in research with exceptional populations. Starting with the pioneering work on the intellectually gifted by Louis Terman (1954), longitudinal research on individuals with exceptionally high levels of GCA have found that they not only excel academically (Lubinski, 2016), but also show lower levels of relationship problems, better physical and psychological health and higher levels of life satisfaction than individuals who are not intellectually gifted (Ferriman, Lubinski, & Benbow, 2009; Terman & Oden, 1959). At the other end of the continuum, individuals with mild intellectual disabilities, characterized by IQs less than 70, have been found to show higher levels of financial dependence, reduced physical health and life expectancy, and greater risk of mental health problems as compared to those without an intellectual disability (Blackorby & Wagner, 1996; Carr et al., 2016; Ellenkamp, Brouwers, Embregts, Joosen, & van Weeghel, 2016).

Largely unaddressed by existing research, whether based on representative samples or exceptional populations, are the educational, occupational, and other social achievements of individuals with low-average levels of GCA. Moreover, the limited research that does exist with this population is typically framed in terms of a deficit model, focused on increased risk of occupational and social problems. Consequently, individuals with low-average GCA have been found to have poorer occupational and educational outcomes and higher levels of behavioral problems as compared to individuals with higher levels of GCA (Fergusson et al., 2005; Hegelund, Flensborg-Madsen, Dammeyer, & Mortensen, 2018). While the finding of deficits is not unexpected, an exclusive focus on problems is unfortunate. Given that they represent a

* Corresponding author at: Department of Psychology, University of Minnesota, 75 East River Rd., Minneapolis, MN 55455, United States of America.
E-mail address: mcgue001@umn.edu (M. McGue).

https://doi.org/10.1016/j.intell.2022.101642
Received 14 August 2021; Received in revised form 4 March 2022; Accepted 4 March 2022
Available online 11 April 2022
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sizable portion of the adult population, individuals with low-average levels of GCA have a substantial impact on societal functioning. As the 1960s era Newsom report concluded, individuals with average or low-average GCA are "politically, socially and economically . . . vital to our national life" (p. xiv, Ministry of Education, 1963). The major aim of the current research is to take up the 60-year-old challenge made in the Newsom report by seeking to identify and characterize the circumstances under which individuals with low-average GCA excel academically and socially.

2. Can high educational attainment compensate for low levels of GCA?

As with GCA, educational attainment is associated with a broad array of desirable outcomes that appear to reflect, at least in part, the causal effects of education (Hout, 2012). College graduates, for example, are more likely than non-graduates to be employed, have a high-status job, earn a high income, and enjoy good health and a long life (Hout, 2012; Lleras-Muney, 2005). The significance of the many outcomes associated with college is reflected by the broad support attaining a college degree receives from both the political class and the general public. Barack Obama, for example, was a well-known champion of the importance of a college degree, famously stating that, "The best investment that we can make in the American Dream is helping every American get a college education. For so many generations, college has been the passport to a better future." (Obama, 2008). We note that such a broadly favorable attitude toward higher education is not universal among American presidents, however. One of Donald Trump's last executive orders directed the federal government to consider skills rather than educational credentials in hiring. Regardless of the growing partisan gulf in attitudes toward education, we seek to address the question of whether the benefits associated with college are experienced broadly, regardless of GCA level.

The high correlation between GCA and educational attainment (Ceci, 1991) as well as the overlapping outcomes with which both have been linked motivate the question of whether GCA and educational attainment independently contribute to social achievements. There is considerable evidence that GCA influences educational attainment (Strenze, 2007), and conversely that educational attainment can contribute to intellectual growth (Ritchie & Tucker-Drob, 2018). The resulting mutual dependence between GCA and educational attainment has made it difficult to resolve their separate contributions. Regression analysis has frequently been used to investigate the joint effects of GCA and educational attainment, although it is not without limitation (Deary & Johnson, 2010). Regardless, these analyses have yielded a consistent set of findings: GCA and educational attainment both contribute independently to the prediction of important life outcomes (Becker, Baumert, Tetzner, Maaz, & Koller, 2019; Caspi, Wright, Moffitt, & Silva, 1998; Scullin, Peters, Williams, & Ceci, 2000). These results, consequently, suggest that the benefits associated with high educational attainment may be broadly experienced, i.e., even among individuals with low levels of GCA.

3. Factors other than GCA that might contribute to educational success

A high level of GCA is often considered essential for college success (Murray, 2009). If there are individuals with low levels of GCA who complete college, to what might we attribute their unexpected success? While there are many potential factors, we focus here on three, not necessarily independent, factors that have received considerable empirical attention and support. Importantly, the association of each of these factors with college completion has been established prospectively, ruling out the possibility of reverse causation (i.e., college causing the factor). First, it is well established that highly educated parents have children who also tend to enjoy educational success (Hertz et al., 2007). Although parent-offspring resemblance may reflect genetic confounding, parent-offspring resemblance for college attainment has been observed in adoptive as well as non-adoptive families (Anderson, Saunders, Willoughby, Iacono, & McGue, 2021), indicating that family background effects cannot be attributed entirely to genetic mechanisms. Importantly in the present context, family background has been found to be associated with the academic success of low-ability students. Using data from the Wisconsin Longitudinal Study, for example, Sewell and Shah (1968) found that the rate of college attendance among individuals with "low intelligence" (defined in their sample as the bottom third of the ability distribution) was only 15.9% if neither parent had attended college but 58.0% when both had.

Personality is the second major non-ability domain with potential to compensate for low GCA (Heckman & Kautz, 2012). The past twenty years have witnessed considerable interest in and research on the role of non-ability personality factors in educational and occupational attainment (Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007). While it is beyond the scope of the present paper to comprehensively summarize this vast literature, several personality factors have received consistent support. Much of the personality research literature is organized around the Big Five model, and Conscientiousness is the Big Five factor most consistently linked with academic and occupational success (Barrick & Mount, 1991; Poropat, 2009). Alternatively, narrower facets of personality have shown stronger associations with social achievement than the broad Conscientiousness factor. The ability to regulate behavior and emotion and delay reinforcement is the personality domain most consistently and strongly linked with social achievement (Duckworth & Seligman, 2005; Ivcevic & Brackett, 2014). There is also considerable support for the importance of motivation and effort for academic success (Richardson, Abraham, & Bond, 2012), as well for the belief that this effort will pay off (McGue, Rustichini, & Iacono, 2017). Importantly, each of these three personality domains (i.e., self-control, achievement motivation, locus of control) are associated with educational and occupational success once the effects of GCA have been taken into account.

Finally, the heritability of educational attainment has been established in scores of studies (Branigan, McCallum, & Freese, 2013), suggesting that genetic factors might also contribute to the academic success of individuals with low levels of GCA. Although genetic factors underlying educational attainment overlap extensively with those for GCA (Malanchini, Rimfeld, Allegrini, Ritchie, & Plomin, 2020; Plomin & von Stumm, 2018), there are genetic factors that contribute to the likelihood of completing college independent of the contribution of GCA (Demange et al., 2020). Large-scale genomewide association studies (GWAS) of educational attainment have led to the identification of genetic variants underlying college completion (Lee et al., 2018). GWAS has also enabled the derivation of polygenic scores (PGS), which represent the aggregate effect of multiple genetic variants. PGS have been used broadly to investigate the nature of genetic contributions to educational attainment and associated traits (Plomin & von Stumm, 2018) and here we explore their utility for understanding the success of individuals with low levels of GCA.

4. Summary and current study

Research has consistently implicated GCA as contributing to educational and occupational attainment, implying that individuals low in GCA will experience less social success than individuals high in GCA. Nonetheless, the imperfect correlation of GCA with social achievement suggests that there are successful individuals with low levels of GCA, perhaps because of their family background, non-ability personality profile or genetic inheritance. Understanding the factors that contribute to the success of individuals with low-average levels of GCA is essential, as they comprise a sizable portion of the population and contribute substantially to the economic and cultural well-being of a society.

To address these and related issues we undertook a longitudinal investigation of a population-based Minnesota sample of 2593 individuals first assessed in adolescence and followed through early adulthood. To evaluate the replicability of our key findings, we also analyzed data from the National Longitudinal Study of Youth (NLSY97), a longitudinal study spanning a similar range of ages. We focus especially on those individuals with IQs $\leq$ 90 who either did or did not complete a college degree to address the following specific questions:

1. To what extent do college-educated individuals with low GCA experience the same social and economic benefits that high ability college graduates do?
2. What factors appear to contribute to the educational success of individuals with low GCA?
3. Are the social and economic benefits associated with completing college consistent with a causal effect of college?

5. Method

5.1. Primary sample: The Minnesota Twin Family Study (MTFS)

Our primary sample was derived from the longitudinal MTFS and was used previously by McGue et al. (2020) to explore the nature of intergenerational social mobility. The original MTFS sample consisted of 1382 pairs of like-sex twins, born in Minnesota between 1972 and 1984 and initially assessed between 1990 and 1996 at a target age of either 11 or 17 years (Iacono, Carlson, Taylor, Elkins, & McGue, 1999). The 11-year-old (younger) cohort was subsequently assessed at target ages of 14, 17, 20, 24 and 29; the 17-year-old (older) cohort was subsequently assessed at target ages of 20, 24 and 29. The last complete follow-up assessments were completed in 2002–2014; ongoing assessments in midlife were not used in the present analysis.

The cohort structure of the original MTFS sample (i.e., the 11- and 17-year-old cohorts) reflects the original primary aim of the MTFS, which was to explore the origins of substance use disorders (for the most part, 11-year-olds have not yet initiated illicit substance use while 17-year-olds are at an age just prior to the peak use of substances for the typical young adult.) Twins in both cohorts were ascertained from birth records maintained by the state of Minnesota, the present location of 91% of which could be determined using various public records. Among eligible twins (i.e., lived within a day's drive of our labs in Minneapolis with no physical or mental handicap, including probable intellectual impairment, that would preclude completing our in-person assessment), 17% declined our invitation to participate. We were able to complete a brief phone interview on 80% of the mothers of non-participating but eligible twins and a comparison to participating twin-families revealed only a few minimal differences. For example, participating parents had significantly more years of education than non-participating parents, although the difference was small (i.e., mean difference of 0.3 years of education for mothers and 0.2 years for fathers). At the time of their intake assessment, the MTFS sample was consequently broadly representative of Minnesota state births. However, Minnesota is not a typical U.S. state and we do not claim broader representativeness. For example, the MTFS twin sample is greater than 93% white, which although consistent with the Minnesota birth years sampled is not consistent with the overall U.S. population (Miller et al., 2012).

Of the 2764 twins who completed an intake assessment, 2593 (93.8%) were included in the current study because they had completed an IQ assessment at intake and reported educational attainment at either the age-29 ($N = 2486$) or, for those who did not complete that assessment, the age-24 ($N = 107$) assessment. Among the 171 intake twins not included in our analyses, 141 were excluded because they did not complete either follow-up, 25 were excluded for unknown educational attainment, and 5 were excluded for missing IQ. The mean (SD) intake IQ score was 99.8 (14.0) for the 2593 included twins versus 95.7 (14.4) for the 164 excluded twins with IQ data, suggesting some selection at follow-up favoring higher GCA.

5.2. MTFS measures

Educational attainment: Was based on participant-reported highest degree at their age-29, or if missing, their age-24 assessment coded as: 1 = Less than High School, 2 = High School or GED, 3 = Some College, 4 = 4-year College, 5 = Graduate or Professional (e.g., M.A., pH.D., M.D.). Codes 4 and 5 were considered to have completed college.

General Cognitive Ability (GCA): Was assessed at intake using an abbreviated form of either the Weschler Adult Intelligence Scale-Revised (WAIS-R, Wechsler, 1981) in the older cohort or the Weschler Intelligence Scale for Children-Revised (WISC-R, Wechsler, 1974) in the younger cohort. In both cases, the abbreviated test consisted of two performance (Block Design and Picture Arrangement) and two verbal (Vocabulary and Information) subtests. Prorated IQs, derived from the four subtests following standard procedures, have been shown to correlate 0.90 with IQs based on all Weschler subtests (Kaufman, 1990). Mean GCA was significantly greater (χ^2 (1df) = 37.8, $p < .001$) in the younger cohort (104.2, SD = 13.9, $N = 1387$) than the older cohort (99.8, SD = 14.1, $N = 1206$), with a modest standardized mean difference, d (95% CI), of 0.31 (0.21, 0.41). Because this difference could reflect a Flynn effect (the WISC-R was normed 7 years before the WAIS-R) as well as other differences in the tests taken (i.e., WISC-R versus WAIS-R), IQ scores were adjusted by subtracting the average difference of 4.4 points from the IQ scores of younger cohort participants.

Social outcomes: Four social outcomes were assessed at either the age-29 or, if unavailable, the age-24 assessment. For those working full-time, occupational status was coded on a reflected 7-point Hollingshead scale (Hollingshead, 1957) so that higher scores corresponded to higher perceived status. Scores on the reflected scale ranged from 1 = unskilled labor to 7 = professional positions. Annual gross income was reported for those who had a job. Because of the marked skewness in the income data, incomes were winsorized at an annual income of $200,000 (eight incomes exceeded this limit, less than 1% of the sample) and log-transformed prior to statistical analysis. An Independence scale was constructed by summing five dichotomous indicators of financial independence (the first four being reflected): 1) government assistance as an adult, 2) unemployment that lasted at least 6 months, 3) living with parents, 4) receiving financial support from parents, and 5) being engaged full-time (i.e., either in a job, or being a full-time student or parent). Finally, a Legal Problems scale was constructed by summing four dichotomous items all reported since the participant's previous assessment: having problems with drugs, police contact, going to court, jailed.

Compensatory Factors: Three additional variables were used to investigate potential mechanisms by which individuals with low GCA could achieve high educational standing. All three measures reflected features of participants that existed prior to the completion of college and so could not be a consequence of college. The first two were assessed when the twins were in adolescence: 1) a composite of five non-ability personality/behavior scales and 2) a composite of three indicators of family socioeconomic status (SES). The personality composite was based on our earlier research (McGue et al., 2020) and consisted of self-report scales measuring a willingness to inhibit behavior, delay reward and work hard along with the belief that doing so would be personally beneficial. Four of the components were scales from the Multidimensional Personality Questionnaire (MPQ, Tellegen & Waller, 2008) and the fifth was a measure of behavioral disinhibition (Hicks, Schalet, Malone, Iacono, & McGue, 2011); all were completed at the age-17 assessment. The MPQ scales included: Social Potency (being decisive), Achievement (ambitious, hard-working), Alienation (feeling exploited, unlucky), and Control (being careful, reflective). The Behavioral Disinhibition scale consisted of aggregated symptoms of antisocial behavior and substance abuse obtained by clinical interview. The Personality composite was formed by taking the mean of the five (or when no more than one was missing, four) standardized components after reflecting the Alienation and Behavioral Disinhibition scores.

Rearing SES was a composite of three indicators reported by parents at the twins' intake assessment: parent education, parent occupation, and family income. Parent education and occupation were assessed as the midparent average using the same scales as used with offspring. Family income was rated on a 1 (less than $10,000/year) to 13 (more than $80,000/year) scale by parents at the intake assessment, completed between 1990 and 1996. The Rearing SES composite was formed by taking the mean of these three standardized indicators (or the mean of two in cases where one was missing). Both the Personality and Rearing SES composites were standardized in the total sample.

Finally, the MTFS sample has been genotyped on over 500,000 single nucleotide polymorphisms (SNPS, Miller et al., 2012), allowing us to compute an educational attainment polygenic score (PGS) using results from the Social Science Genetics Association Consortium's most recent GWAS of educational attainment (Lee et al., 2018). PGS involve deriving an aggregate index of the genetic effect by taking a weighted sum of all individual genetic variants, where information on the weights is based on a large GWAS. PGS for the current analyses were computed using the LDpred software with a prior probability of 1.0 (Vilhjálmsson et al., 2015). Because genetic prediction varies by ancestral background (Martin et al., 2017), PGS were calculated only for the 93% of the sample determined to have European ancestry (Miller et al., 2012).

5.3. Analysis of the MTFS sample

Group Classification: The 2 × 3 (College by GCA) design used in the current study involved crossing whether the participant had or had not completed a 4-year college degree with a 3-level classification of GCA (i.e., Low, Medium, and High). Converting a continuous measure into discrete categories can introduce arbitrariness into the analysis. Nonetheless, GCA categorization was central to our aim of investigating the social outcomes associated with low levels of measured intelligence. To minimize the potential for arbitrariness, we considered two factors in deciding group thresholds. First, had the cutpoints been established in earlier clinical practice or research? Second, could we validate the utility of previously established cutpoints by linking them with educational attainment in the MTFS sample? These considerations led us to the following classification: Low GCA = IQ of 90 or less, Medium GCA = IQ between 90 and 110, and High GCA = IQ of 110 or more. There are several classification schemes for defining meaningful discrete subsamples based on IQ. In most of these classifications, a cutpoint of 90 is used to demarcate individuals with low-average or lower intellectual functioning, and a cutpoint of 110 is used to identify individuals with high-average or higher intellectual functioning (Gregory, 1995). These cutpoints have been used in other largescale research studies of intelligence. For example, in a recent survey of social outcomes in more than one million Danish men, Hegelund et al. (2018) used the 90 cutpoint to identify a group of "low IQ" men. Further, the lower threshold of 90 is approximately equal to the mean (95% CI) IQ of 90.2 (87.1, 93.3) for the 41 MTFS participants who did not complete a high school or GED degree, while the upper threshold of 110 is approximately equal to the mean IQ of 108.3 (106.9, 109.7) for the 442 individuals with a graduate or professional degree (Fig. 1). Thus, the cutpoints we used had prior justification and were functionally linked with educational attainment in the MTFS sample (e.g., an IQ of 90 was typical for someone not completing high school.)

The effects of GCA level and College were evaluated using a generalized linear model with generalized estimating equations (GEE) to account for the clustering of the data by twin pair (Hanley, Negassa, Edwardes, & Forrester, 2003). Our initial analysis sought to determine whether the benefits associated with a college education existed independent of GCA level. This analysis involved fitting a three-factor (Sex by GCA by College) analysis of variance (ANOVA) separately for each of the four social outcome scales. In these analyses, the main effect of College would establish an association between the social outcome and college completion, while the College by GCA interaction would test whether the College effect varied by GCA level. Occupation and Log Income were fit assuming a normal distribution with identity link function; Independence (reflected) and Legal Problems (reflected) were fit using a negative binomial distribution and log link function. In all analyses, age at assessment, ethnicity (limited to white versus non-white given the structure of the sample), and birth year were included as covariates and dependent variables were standardized to facilitate interpretation. We report Type III test of effects and estimates of standardized group differences (d) along with confidence intervals.

Our second stage of analysis sought to determine whether the potential compensatory factors (i.e., Personality, Rearing SES and the PGS) could account for the educational success of individuals with low GCA.

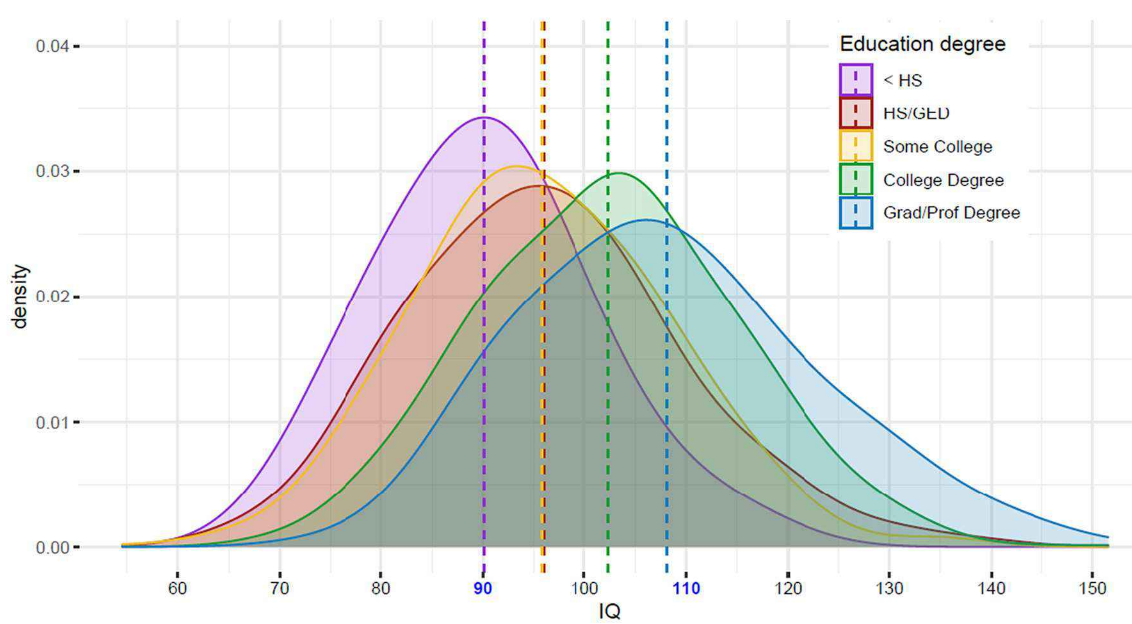

Fig. 1. Distribution of IQs as a function of highest degree completed in MTFS sample ($N = 2593$). Dashed lines give mean IQ as a function of educational attainment group, thresholds for defining the low GCA (90) and high GCA (110) groups highlighted in blue. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Two analyses were undertaken. First, we investigated whether college completion was associated with each of the three compensatory factors by including them as dependent variables in a three-factor (Sex by GCA by College) ANOVA. A College main effect would indicate a significant mean difference between college and non-college participants on the factor net GCA, while a significant College-by-GCA interaction would indicate that the magnitude of the College effect varied by GCA level. Second, we included the three compensatory factors as covariates in the ANOVA model used in the first stage to determine the extent to which their inclusion could account for the College effect on each social outcome.

The final stage in our analysis involved using the cotwin control (CTC) method to assess whether the college effects identified at the first stage were consistent with a causal effect (McGue, Osler, & Christensen, 2010). As is true with any method for analyzing observational data, CTC analysis does not purport unequivocally to establish causality. Rather, it seeks to determine whether an association is consistent with causality using a test that is more stringent than the standard approach of statistically correcting for measured confounders. The CTC method derives its rationale from the counterfactual model of causality. By comparing outcomes in twins discordant on exposure (here completion of college), CTC analysis in effect uses one twin (i.e., the college-completing twin) as an approximation to the counterfactual for the cotwin (i.e., the non-college-completing twin.) The power of the CTC approach is a consequence of the matching of the twins. In our application of the CTC method, we investigated only monozygotic (MZ) twin pairs discordant for college completion, which controls for confounding due to genetic and rearing environmental factors because MZ twins are perfectly matched on these factors even when they are discordant for college completion. The use of the CTC method to assess the returns to education has a long history in economics and psychology (Ashenfelter & Krueger, 1994; Stanek, Iacono, & McGue, 2011). In implementing the CTC analysis here, we followed the procedures described by Saunders, McGue, and Malone (2019) for covariate adjustment.

All MTFS participants that met study inclusion criteria were included in the analyses. Because of the large number of statistical tests reported, we both used a significance level of $p < .005$ (Benjamin et al., 2018) to minimize false positive reports and emphasized effect size rather than statistical significance. Power calculations are complex in a multi-objective study with clustered sampling. We conservatively assessed power based on number of families and in two-group comparisons we have power of 0.80 or greater to detect mean differences of 0.2 SD or greater at $p < .005$ (two-tailed).

5.4. Description and analysis of the secondary sample: National Longitudinal Survey of Youth, 1997 (NLSY97)

The NLSY97 sample (Bureau of Labor Statistics, 2019) was used to assess robustness of key findings from the MTFS. Although there is no sample that perfectly duplicates the MTFS twin structure and assessments, the NLSY97 has the advantage of being a U.S. longitudinal study that spans adolescence through early adulthood and includes birth cohorts that overlap those in the MTFS. The NLSY97 included individuals born between 1980 and 1984 who were first assessed in 1997 and followed annually through 2011 and biannually thereafter. To approximate the MTFS sample, we made use only of what is known as the cross-sectional NLSY97 sample (i.e., the sample selected to be representative of the U.S.), which numbered 6748 at the initial assessment. The ethnic distribution of this sample was 16% Black, 14% Hispanic, 69% Non-Hispanic White and 1% mixed.

The specific variables used from the NLSY97 along with their variable codes are listed in Table S1 (Supplemental Online Material, SOM). Education was coded as highest degree completed on the same 5-point scale used in the MTFS. The NLSY97 did not administer an IQ test but did administer an ASVAB Verbal-Math composite in 1999. These composite scores were converted to IQ equivalents (i.e., mean of 100 and standard deviation of 15). Occupation was based on the 4-digit census code derived in 2015, and log Income was based on the 2011 report. We also computed an Assistance scale by summing ever receiving unemployment benefits and ever receiving government assistance; and a Legal Problems scale by summing ever arrested, use of marijuana, and use of other illicit drugs from the 2011 and 2015 assessments, respectively.

6. Results

6.1. Initial analysis of the MTFS sample

GCA, the four social outcomes (Occupation, Income, Independence, Legal Problems) and three compensatory factors (Personality, SES, PGS) were all monotonically related to highest educational degree completed with the single exception of those not graduating high school having a higher mean income than those with a high school degree among men, perhaps because they had been in the workforce for longer (Table S2, SOM). There was marked variability in GCA within each degree group (Fig. 1), such that some with a college degree had relatively low GCA. Table 1 gives the sample size and descriptive statistics for study variables as a function of the College by GCA grouping, separately for women and men (descriptive data pooled over sex is reported in Table S3, SOM). Of note is that 147 (10.8% of the total sample) of women but only 45 (3.7%) of men were in the low GCA-College group.

Given the expansion of educational opportunity that occurred in the U.S. during the 20th century, it is informative to compare rates of college completion among offspring with that of their parents. Among offspring, 53.0% of women ($N = 1365$, 95% CI = 50.3%, 55.7%) and 40.3% of men ($N = 1228$, 95% CI = 37.6%, 43.0%) had completed college. Among their parents, 25.3% of mothers ($N = 1315$, 95% CI = 23.4%, 28.2%) and 28.0% of fathers ($N = 1311$, 95% CI = 25.4%, 30.6%) had a college degree. While all GCA groups saw an increase in college completion between the parent and offspring generations, the largest proportional increase was in the low GCA group, where the increase in college completion was more than 10-fold among women and nearly 6-fold among men (Fig. 2).

Correlations among study variables are reported in Table 2. Both GCA and educational attainment were moderately correlated with all outcomes, with correlations for the latter being consistently greater than those for the former. Descriptive statistics are given in Table S4 (SOM) for the individual components comprising the Independence and Legal Problems scales and in Table S5 (SOM) for components of the Personality and Rearing SES composites. Table S6 (SOM) gives the intercorrelations among the individual components used in forming the composites.

GCA group status was based on observed IQ, which could lead to selection on measurement error, especially at the extremes (e.g., IQ $\leq$ 90 for the Low GCA group). Of the 2593 individuals in the sample, 1683 (65%) had completed a second IQ assessment (based on the same four WAIS-R subtests used at the initial assessment) on average 6.6 years (SD = 0.7) after the first (complete results in Table S7 and Fig. S1, SOM). Those retested had a slightly higher mean IQ at initial testing (mean = 101.0, SD = 13.9, $N = 1683$) than those not retested (mean = 97.5, SD = 13.8, $N = 910$), with the correlation between the two assessments being 0.79 (95% CI =0.77, 0.81). As expected, the 122 individuals in the Low GCA-College group with two IQ assessments scored lower at the initial assessment used to form the GCA groups (mean = 85.1, SD = 4.7) than at retest (mean = 91.8, SD = 9.1) and the 119 individuals in the High GCA-No College group with two IQ assessments scored higher at initial assessment (mean = 117.9, SD = 6.8) than retest (mean = 115.1, SD = 12.3). Although the mean IQs for the low GCA and high GCA groups are likely somewhat biased due to selection, both groups are clearly extreme on the IQ distribution.

Table 1
Descriptive data on study variables by group membership separately by sex in MTFS sample.

		Women (Total N = 1365)						Men (Total N = 1228)					
		NO COLLEGE			COLLEGE			NO COLLEGE			COLLEGE		
		Low GCA	Med GCA	High GCA	Low GCA	Med GCA	High GCA	Low GCA	Med GCA	High GCA	Low GCA	Med GCA	High GCA
N	%	279	311	52	147	378	198	203	406	124	45	261	189
		20.4%	22.8%	3.8%	10.8%	27.7%	14.5%	16.5%	33.1%	10.1%	3.7%	21.3%	15.4%
IQ	Mean	81.4	98.7	117.2	84.6	100.9	119.3	83.6	99.5	118.3	85.1	100.9	120.9
	(SD)	(6.3)	(5.3)	(5.2)	(5.1)	(5.5)	(7.7)	(6.2)	(5.5)	(7.5)	(4.4)	(5.5)	(8.4)
Demographics:													
Age	Mean	29.2	29.2	29.2	29.2	29.2	29.1	29.3	29.2	29.3	29.5	29.4	29.5
	(SD)	(1.2)	(0.9)	(0.9)	(0.9)	(0.9)	(0.9)	(1.2)	(1.2)	(1.3)	(0.7)	(0.9)	(0.8)
Married	%	57.8%	57.5%	64.7%	68.8%	63.6%	54.5%	47.1%	50.4%	50.0%	60.0%	59.5%	49.5%
Ethnicity	%	93.8%	91.5%	94.2%	87.7%	97.0%	94.9%	90.1%	93.8%	88.6%	100.0%	93.4%	93.0%
Birth Year	Mean	1979.8	1980.1	1980.6	1979.8	1980.2	1980.6	1977.6	1978.0	1977.4	1978.2	1977.6	1978.0
	(SD)	(3.1)	(2.9)	(2.9)	(3.0)	(2.9)	(3.1)	(3.0)	(2.9)	(3.0)	(3.0)	(3.2)	(3.1)
Social Outcomes:													
Occupation	Mean	3.66	3.96	4.32	5.06	5.33	5.59	3.20	3.56	3.90	5.48	5.29	5.59
	(SD)	(1.34)	(1.37)	(1.29)	(1.28)	(1.06)	(1.04)	(1.49)	(1.52)	(1.54)	(0.94)	(1.28)	(1.21)
Income	Mean	29.4	31.7	36.7	42.2	44.6	45.7	49.0	46.1	45.3	57.5	61.5	57.1
	(SD)	(17.8)	(16.4)	(25.4)	(20.3)	(21.1)	(25.6)	(33.3)	(22.7)	(22.1)	(35.6)	(34.5)	(35.3)
Independence	Mean	4.20	4.29	4.39	4.65	4.72	4.53	4.26	4.34	4.46	4.62	4.71	4.70
	(SD)	(0.98)	(0.89)	(0.87)	(0.77)	(0.59)	(0.77)	(0.96)	(1.00)	(0.80)	(0.72)	(0.63)	(0.64)
Legal	Mean	0.36	0.29	0.08	0.11	0.08	0.08	0.68	0.50	0.53	0.22	0.31	0.22
Problems	(SD)	(0.80)	(0.77)	(0.27)	(0.47)	(0.28)	(0.38)	(1.20)	(1.04)	(1.07)	(0.67)	(0.85)	(0.73)
Compensatory Factors:													
Personality	Mean	−0.47	−0.34	0.00	0.28	0.39	0.56	−0.39	−0.31	−0.32	0.26	0.27	0.33
	(SD)	(0.95)	(1.05)	(1.03)	(0.89)	(0.94)	(0.89)	(0.85)	(0.96)	(0.94)	(0.80)	(0.80)	(0.91)
Rearing SES	Mean	−0.54	−0.31	−0.01	0.15	0.34	0.76	−0.48	−0.39	−0.03	0.13	0.34	0.68
	(SD)	(0.72)	(0.87)	(0.98)	(0.90)	(0.96)	(1.02)	(0.86)	(0.83)	(0.90)	(0.87)	(0.93)	(1.04)
PGS	Mean	−0.48	−0.13	−0.05	−0.26	0.24	0.60	−0.33	−0.13	0.04	0.01	0.22	0.54
	(SD)	(0.93)	(0.94)	(0.86)	(1.01)	(0.94)	(0.93)	(1.01)	(0.96)	(0.97)	(1.07)	(0.94)	(0.88)

Note: GCA = General Cognitive Ability; SES = Socioeconomic Status; PGS = Educational Attainment Polygenic Score. Income is annual net income in thousand dollars. Ethnicity gives percentage white ethnicity.

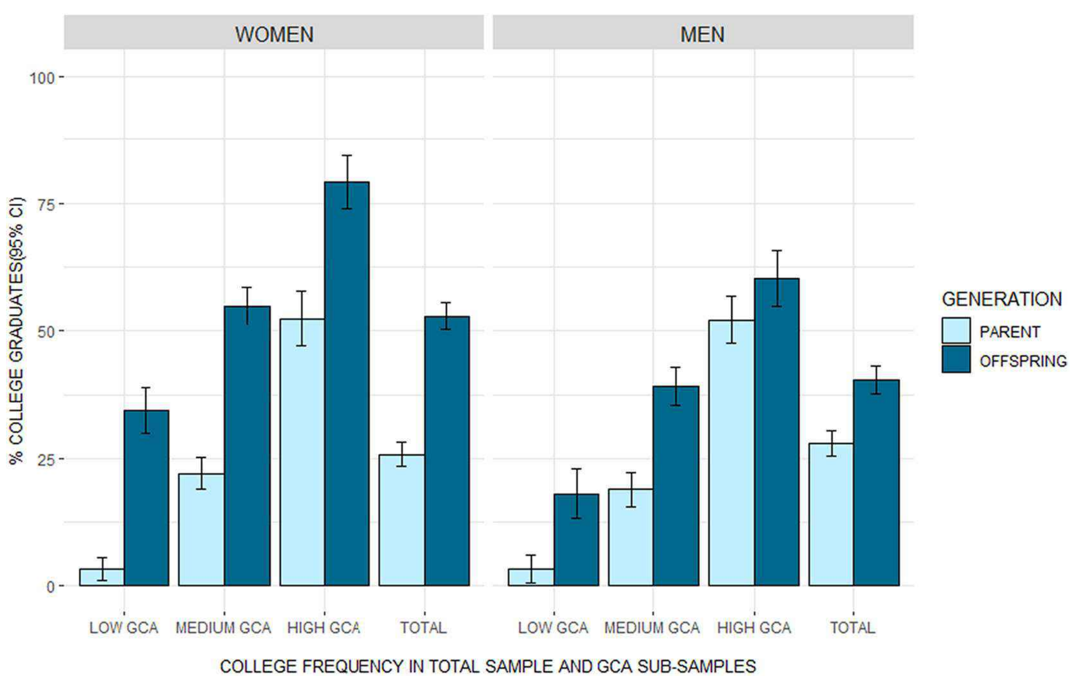

Fig. 2. Expansion of college completion in the MTFS sample. Figure gives the percentage (95% CI) college completion in the parent and offspring generations both in the total sample and as a function of GCA grouping.

6.2. *Association of GCA and college with social outcomes in young adulthood in the MTFS*

ANOVA results for the four social outcomes are given in Table 3 under the column labelled Base. In only one case was there a statistically significant (at $p < .005$) two-way or three-way interaction (the Sex by College interaction for Occupation, where the College effect was greater in men than women). Notably, there was no evidence that the College effect varied by GCA level, indicating that the magnitude of the College effect was statistically as great for those with low GCA as with those with

Table 2

Descriptive statistics and intercorrelations (sample size) for study variables in MTFS sample.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	1.0												
2. Sex	−0.07	1.0											
	N = 2593												
3. Ethnicity	0.12	0.02	1.0										
	N = 2564	N = 2564											
4. Birth Year	−0.27	0.37	−0.03	1.0									
	N = 2593	N = 2593	N = 2564										
5. Education	0.03	0.14	0.04	0.07	1.0								
	N = 2593	N = 2593	N = 2564	N = 2593									
6. GCA	0.04	−0.14	0.04	−0.02	0.32	1.0							
	N = 2593	N = 2593	N = 2564	N = 2593	N = 2593								
7. Occupation	0.01	0.11	0.03	0.02	0.55	0.29	1.0						
	N = 2217	N = 2217	N = 2197	N = 2217	N = 2217	N = 2217							
8. Log Income	0.06	−0.26	0.01	−0.08	0.20	0.12	0.37	1.0					
	N = 2207	N = 2207	N = 2187	N = 2207	N = 2207	N = 2207	N = 2200						
9. Independence	0.06	−0.01	0.04	−0.10	0.23	0.13	0.25	0.32	1.0				
	N = 2478	N = 2478	N = 2456	N = 2478	N = 2478	N = 2478	N = 2217	N = 2207					
10. Legal Problems	0.05	−0.15	−0.06	−0.03	−0.20	−0.09	−0.17	−0.05	−0.20	1.0			
	N = 2483	N = 2483	N = 2461	N = 2483	N = 2483	N = 2483	N = 2217	N = 2207	N = 2478				
11. Personality Composite	0.04	0.06	0.02	0.02	0.36	0.18	0.34	0.18	0.16	−0.15	1.0		
	N = 2373	N = 2373	N = 2353	N = 2373	N = 2373	N = 2373	N = 2034	N = 2024	N = 2271	N = 2276			
12. Rearing SES Composite	−0.01	0.03	0.01	0.03	0.40	0.31	0.28	0.13	0.13	−0.10	0.18	1.0	
	N = 2589	N = 2589	N = 2560	N = 2589	N = 2589	N = 2589	N = 2214	N = 2474	N = 2204	N = 2479	N = 2369		
13. PGS	0.03	−0.01	NA	0.01	0.27	0.29	0.21	0.09	0.07	−0.08	0.12	0.24	1.0
	N = 2390	N = 2390		N = 2390	N = 2390	N = 2390	N = 2071	N = 2062	N = 2307	N = 2312	N = 2194	N = 2386	
SAMPLE MEAN	29.3	1.53	0.93	1979.0	3.33	99.8	4.51	3.67	4.48	0.30	0.00	0.01	0.01
(SD)	(1.0)	(0.50)	(0.25)	(3.2)	(1.11)	(14.0)	(1.58)	(0.60)	(0.84)	(0.81)	(1.00)	(1.00)	(1.00)
	N = 2593	N = 2593	N = 2593	N = 2593	N = 2593	N = 2593	N = 2217	N = 2207	N = 2478	N = 2483	N = 2373	N = 2589	N = 2390

Note: The standard error for an estimated correlation is no greater than 0.02 in a sample of 2000 and 0.03 in a sample of 1000. Sex coded as 1 = male, 2 = female; Ethnicity coded as 1 = white, 0 = other; Education coded as 1 = less than high school, 2 = high school or GED, 3 = some college, 4 = completed college and 5 = graduate or professional degree; and Occupation was reverse-coded on the 1–7 Hollingshead scale for those having a job. GCA = General Cognitive Ability assessed on an IQ scale. SES = Socioeconomic status. PGS = polygenic score (for educational attainment). NA = correlation not computable because only used when Ethnicity = 1.

Table 3
ANOVA Results for social outcomes in the MTFS sample

	Occupation		Log Income		Independence		Legal Problems	
Effect (test statistic df)	Base χ^2 p	Adjusted χ^2 P	Base χ^2 p	Adjusted χ^2 P	Base χ^2 P	Adjusted χ^2 p	Base χ^2 p	Adjusted χ^2 p
Age (1df)	1.21 $p = .27$	1.03 $p = .31$	2.55 $p = .11$	1.32 $p = .25$	0.46 $p = .50$	0.42 $p = .52$	3.23 $p = .07$	0.00 $p = .96$
Sex (1df)	8.53* $p = .003$	4.37 $p = .037$	98.5* $p < .001$	91.66* $p < .001$	0.05 $p = .82$	0.01 $p = .93$	41.85* $p < .001$	25.10* $p < .001$
Ethnicity (1df)	0.20 $p = .66$	NA	0.01 $p = .93$	NA	1.54 $p = .22$	NA	2.81 $p = .09$	NA
Birth Year (1df)	3.73 $p = .053$	2.33 $p = .13$	1.16 $p = .28$	1.92 $p = .17$	17.42* $p < .001$	13.73* $p < .001$	6.04 $p = .014$	0.58 $p = .45$
GCA Group (2df)	30.55* $p < .001$	12.47* $p = .002$	1.87 $p = .39$	2.52 $p = .28$	2.91 $p = .23$	1.38 $p = .50$	6.07 $p = .048$	1.59 $p = .45$
College (1df)	584.2* $p < .001$	308.1* $p < .001$	71.9* $p < .001$	31.81* $p < .001$	61.35* $p< .001$	30.80* $p < .001$	37.35* $p < .001$	12.41* $p < .001$
GCA x College (2df)	5.98 $p = .05$	6.99 $p = .030$	1.62 $p = .45$	1.01 $p = .60$	4.73 $p = .094$	1.93 $p = .38$	4.24 $p = .12$	2.08 $p = .35$
Sex x College (1df)	15.92* $p < .001$	12.12* $p = .001$	4.13 $p = .04$	4.03 $p = .045$	0.02 $p = .88$	0.05 $p = .83$	5.10 $p = .024$	2.83 $p = .09$
Sex x GCA (2df)	2.57 $p = .28$	0.34 $p = .85$	2.60 $p = .27$	1.53 $p = .47$	1.92 $p = .38$	3.16 $p = .21$	0.65 $p = .72$	0.09 $p = .96$
Sex x College x GCA (2df)	3.47 $p = .18$	4.26 $p = .12$	1.44 $p = .49$	3.16 $p = .21$	2.20 $p = .33$	3.58 $p = .17$	4.51 $p = .11$	4.80 $p = .09$
Personality (1df)	NA	65.98* $p < .001$	NA	18.86* $p < .001$	NA	16.39* $p < .001$	NA	17.47* $p < .001$
Rearing SES (1df)	NA	6.05 $p = .014$	NA	1.42 $p = .23$	NA	3.06 $p = .08$	NA	1.19 $p = .28$
PGS (1df)	NA	11.42* $p = .001$	NA	0.73 $p = .39$	NA	0.00 $p = .97$	NA	0.39 $p = .53$

NA: Base model did not include Personality and Rearing SES composites and PGS as covariates while Adjusted model did. PGS only available on white participants and so cannot be included in model with Ethnicity.
[*] $p < .005$; PGS = polygenic score for educational attainment.

medium or high GCA. We consequently focus on the main effects for College and GCA (note that the effect for each factor is net the contribution of the other factor). College was significantly associated with all four outcomes at $p < .001$; GCA was significantly associated with Occupation only. Standardized marginal mean differences (i.e., effect estimates are net other independent variables in the model) between those completing college and those not both in the total sample as well as by GCA level are plotted in Fig. 3A. In the total sample, College was associated with markedly higher occupational status ($d = 1.03$, 95% CI = 0.95, 1.11), moderately higher income ($d = 0.45$, 95% CI = 0.34, 0.55) and independence ($d = 0.36$, 95% CI = 0.27, 0.46) and modestly lower legal problems ($d = -0.23$, 95% CI = -0.16, −0.31). As can be seen in Fig. 3A, the magnitude of the estimated College effect varied minimally across GCA groups, consistent with the non-significance of the GCA by College interaction effect reported in Table 3. The only significant main effect of GCA was on occupational status, where the standardized mean difference comparing the low with the high GCA group was $d = 0.32$ (95% CI = 0.21, 0.43). There might be concern that our failure to observe a significant GCA by College interaction effect may be a consequence of our categorization of GCA into groups rather than treating it as a continuous variable. Of course, the group categorization is central to our study's aim to understand the achievements of individuals low in GCA. Nonetheless, we investigated the impact of analyzing GCA as a continuous variable and again failed to observe a significant interaction effect. These results are summarized in Table S8 (SOM). The magnitude of a statistical interaction does depend on the scaling of the independent variables, and the particular scaling of GCA measurement lacks the strong justification for the scaling of physical attributes such as length and temperature (Jensen, 2006; McDonald, 1999). It is rather striking, nevertheless, that the conventional scaling of GCA leads for the most part to an absence of statistical interaction with College in the prediction of our outcomes. Zero is a salient possible magnitude of interaction that happens to be a priori very unlikely. If such a special result is taken as evidence for the correctness of the GCA scaling, then the conventional scaling such that the GCA measurement has a normal distribution in a norming sample obtains further support.

6.3. Personality, rearing SES and educational attainment polygenic score as compensatory factors

Table 4 gives the ANOVA results for the Personality and Rearing SES composites as well as for the educational attainment PGS. None of the interactions was statistically significant, and we focus on the main effects for College and GCA. College was significantly associated with all three candidate compensatory factors, with the standardized marginal mean difference between those with and without a college degree being strong for both the Personality ($d = 0.65$, 95% CI = 0.55, 0.75) and Rearing SES ($d = 0.69$, 95% CI = 0.59, 0.80) composites and moderate for the PGS ($d = 0.42$, 95% CI = 0.30, 0.53). GCA was significantly associated with Rearing SES (High versus Low GCA group $d = 0.53$, 95% CI = 0.38, 0.68) and the PGS (High versus Low GCA group $d = 0.55$, 95% CI = 0.39, 0.71) but not with the Personality composite (High versus Low $d = 0.22$, 95% CI = 0.08, 0.35) based on our $p < .005$ threshold.

Including the three potential compensatory factors in the ANOVA model for the four social outcomes (column labelled Adjusted in Table 3), reduced but did not eliminate the College effect. In the fully adjusted ANOVA model, only the Personality composite was significantly associated with all four social outcomes, Rearing SES was not significantly associated with any of the four outcomes and the PGS was only significantly associated with Occupation. A comparison of the standardized mean difference, d, between college and non-college participants is given in Fig. 4. The estimates labelled Total give d when adjustment is made only for demographic factors; those labelled Base give the marginal mean difference obtained under the Base model from Table 3 and so further adjusts for GCA grouping; and those labelled Adjusted are for the fully adjusted model in Table 3 and so further

Fig. 3. Standardized marginalized mean difference (95% CI) between college graduates versus non-graduates in the MTFS (A) and NLSY97 (B) samples for social outcomes. College effect is given both in the toal sample (dark blue) and as a function of GCA grouping (light blue). The magnitude of college effect did not vary significantly by GCA group for all social outcomes in both samples. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

correct for the three candidate compensatory factors. Although the fully adjusted estimates are reduced relative to the Base model, reflecting the impact of the compensatory factors, the difference is generally small. For example, the College effect on occupational status under the Base model was $d = 1.03$ (95% CI = 0.95, 1.11), which was reduced to $d = 0.88$ (95% CI = 0.77, 0.96) under the fully adjusted model.

6.4. *Co-twin control analysis of the MTFS sample*

CTC analysis sought to determine whether associations of college with outcomes were consistent with a causal college effect (McGue et al., 2010). MZ twins discordant for college attainment are perfectly matched on their genomes and rearing environment. Consequently, if college contributes causally to social and economic outcomes, we expect the college educated twin to score higher on these outcomes than their non-

Table 4
ANOVA Results for Candidate Compensatory Factors in the MTFS sample.

Effect (test statistic df)	Personality χ^2 P	SES χ^2 p	PGS χ^2 p
Age (1df)	1.07 $p = .30$	2.12 $p = .15$	0.86 $p = .35$
Sex (1df)	4.53 $p = .03$	0.18 $p = .67$	0.83 $p = .36$
Ethnicity (1df)	0.01 $p = .94$	0.02 $p = .89$	NA
Birth Year (1df)	0.50 $p = .48$	0.11 $p = .75$	0.00 $p = .96$
GCA Group (2df)	9.73* $p = .008$	51.8* $p < .001$	44.97* $p < .001$
College (1df)	165.0* $p < .001$	175.8* $p < .001$	51.51* $p < .001$
GCA x College (2df)	0.53 $p = .77$	0.29 $p = .87$	4.03 $p = .13$
Sex x College (1df)	0.38 $p = .54$	0.01 $p = .93$	0.00 $p = .96$
Sex x GCA (2df)	5.72 $p = .06$	0.28 $p = .87$	3.68 $p = .16$
Sex x College x GCA (2df)	1.14 $p = .57$	0.95 $p = .62$	1.08 $p = .58$

NA – All participants with a PGS (polygenic score) were white so Ethnicity cannot be included in a model with PGS. * $p < .005$

college educated cotwin. The strength of the CTC method is that it controls for confounding attributable to genetics and rearing environmental effects without explicitly measuring these confounders. The MTFS sample included 818 pairs of MZ twins, 347 concordant for not having a college degree, 319 concordant for college and 152 discordant. Results of the CTC analyses are summarized in Fig. 4 and Table S9 (SOM). College-completing MZ twins had higher means on all four outcomes than their non-college completing cotwins, although this difference was generally modest in magnitude ($d < 0.25$) and non-significant except for occupational status (χ^2 (1df) = 33.6, $p < .001$, $d = 0.54$, 95% CI = 0.36, 0.72). The college-completing twin also scored on average higher on IQ (mean difference of 1.8 IQ points, 95% CI = 0.4, 3.2) and the Personality composite ($d = 0.49$, 95% CI = 0.32, 0.67), although adjusting within-pair differences on social outcomes for these potential confounders had minimal effect on estimates (Table S9).

6.5. *Analysis of the NLSY97*

Analysis of the NLSY97 sought to replicate our MTFS finding that individuals low in GCA who complete college experience the social and economic benefits associated with college. Means and SDs of the NLSY97 sample, grouped by GCA-College group, are given in Table S10. Although the NLSY97 included individuals with low GCA (i.e., an IQ $\leq$ 90) who completed a college degree, their proportionate representation was less than what we observed in the MTFS sample. Among the 752 women in the NLSY97 sample with IQ $\leq$ 90, 8.6% (95% CI = 6.6%, 10.6%) completed college, while the comparable rate among 915 men was 7.4% (95% CI = 5.7%, 9.1%).

The ANOVA results for the four social outcomes in the NLSY97 sample are summarized in Table S11 and closely paralleled those from the MTFS. College and GCA group were significantly associated with all four outcomes with no evidence of an interaction between the two factors. Estimates of the marginal standardized difference between the college and non-college group are plotted in Fig. 3B, both overall and as a function of GCA group level.

7. Discussion

Our analysis of longitudinal data spanning adolescence through early adulthood sought to address three related questions: 1) Are the social and economic benefits associated with completing college available to those with low levels of GCA? 2) What factors might contribute to the academic success of individuals low in GCA who complete college? And 3) Are the associations of college with social and economic outcomes consistent with a causal effect of college? Our discussion is organized around these three questions.

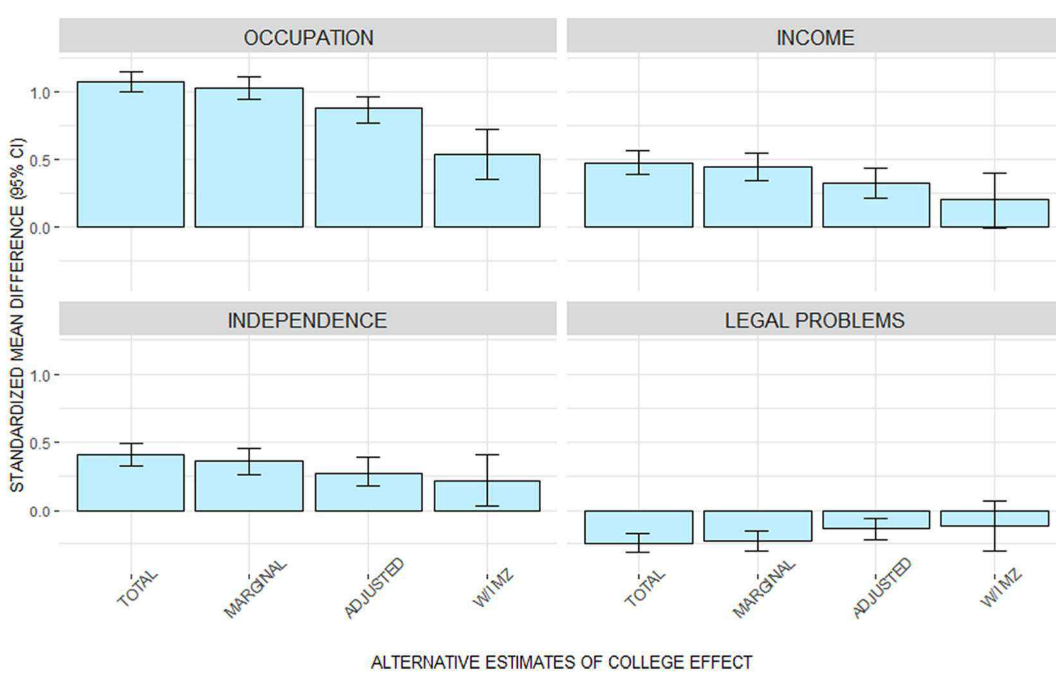

Fig. 4. Standardized mean difference (95% CI) between College and Non-College samples in the MTFS for four social outcomes. Total gives mean difference adjusted only for the demographic factors of Age, Sex, Ethnicity and Birth Year. Base is the marginal estimate (i.e., averaged across General Cognitive Ability groups), and so further adjusts for GCA. Adjusted gives the fully adjusted estimate from the model that also included the Personality and Family SES composites and the PGS as covariates. W/i MZ gives the mean difference within monozygotic twin pairs discordant for college completion.

7.1. The benefits associated with college among individuals with low levels of GCA

Young adults increasingly receive the message that college is key to their future economic and social well-being, encouragement that appears to be having an impact. In the U.S., the frequency of completing a college degree has increased from 5% in 1940 to 33% in 2015 (Ryan & Bauman, 2016); in 2019 approximately 2/3rds of U.S. high school graduates matriculated to college (United States Bureau of Labor Statistics, 2021). Nonetheless, some scholars have expressed concern that increases in college attendance might not always be good, that college may not be for everyone (Owen & Sawhill, 2013). The expansion of college enrollment has been accompanied by declining selectivity among U.S. colleges especially at the lowest levels of selectivity (Hoxby, 2009) and perhaps, as a consequence, lower levels of literacy have been observed among graduates (Kutner et al., 2007).

Data from our Minnesota sample is consistent with this literature. College attainment expanded markedly between the parent and offspring generations, especially among individuals at the lowest level of GCA. Although most individuals with IQs ≤ 90 in both generations did not complete a college degree, the rate of college completion in this group increased approximately 6-fold (in men) and 10-fold (in women) between the parent and offspring generations. Individuals with IQs between 80 and 90 are typically labelled as low-average (Sattler, 2020), and although they constitute a sizable segment of the population, they have received limited empirical attention. We consequently know little about the nature of their academic experiences and successes, a gap we sought to address in the present study.

Research on the returns to college education has typically focused on income, yet the goals of higher education typically extend beyond a singular focus on financial well-being (Whitfield, Perry, & Kelly, 2016). Consequently, we investigated not only wage income but also occupational status, financial independence and legal problems. Consistent with earlier research, we found that completing a college degree was associated with all four social outcomes, with the magnitude of the college effect being large for occupational status, moderate for income and financial independence, and modest, but still significant, for legal problems. Importantly, the magnitude of the college effect on these outcomes did not vary significantly by GCA level. College was neither the great equalizer (i.e., it did not reduce GCA differences, Torche, 2011) nor a producer of a Matthew effect (i.e., it did not expand differences, Damian, Su, Shanahan, Trautwein, & Roberts, 2015). Those with low levels of GCA appeared to benefit from college to the same degree as those high in ability. Importantly, we were able to replicate this key finding from the Minnesota sample in the independent NLSY97 sample.

7.2. Factors that might compensate for low levels ***of GCA***

Our findings are consistent with a growing literature suggesting a range of factors in addition to GCA can contribute to social success (Roberts et al., 2007). We investigated three such factors: 1) non-ability personality factors related to self-control, the delay of gratification and willingness to work hard (McGue et al., 2017); 2) rearing SES (Anderson et al., 2021); and 3) genetic endowment (Lee et al., 2018). We found that college attainment was significantly associated with all three of these factors independently of GCA, with the magnitude of the college/non-college difference being large for the Personality and Rearing SES composites and moderate for the PGS. Nonetheless, in aggregate these factors accounted for only a small portion of the College effect on the four social outcomes, suggesting that other factors, not assessed in our study, must also be contributing to the academic success of individuals with low levels of GCA. A long list of potential compensatory factors has been identified in previous research, including social capital (Portes, 1998), peer norms (Ryan, 2000) and a broader array of non-ability personality factors than we assessed (Smithers et al., 2018). The role of grade inflation should also be considered. There is concern that grade inflation at the high school level has resulted in increasing numbers of poorly prepared students being admitted to U.S. colleges (Gershenson, 2018), and that grade inflation at the college level has resulted in some students completing a college education without acquiring academic skills (Denning, Eide, Mumford, Patterson, & Warnick, 2021).

It is interesting to consider our findings in the context of recent discussions in the U.S. about ending the use of standardized ability/aptitude tests for college admissions. Our results do not imply that GCA is irrelevant for academic success nor that colleges would be better off if they admitted students without regard to their level of cognitive ability. There is ample evidence of the importance of GCA to educational attainment (Strenze, 2007). Moreover, previous attempts to relax cognitive screens without a suitable alternative, such as the Vietnam-era Project 100,000 where individuals scoring below the 10th percentile on the Armed Forces Qualifying Test were recruited into the military (Laurence & Ramsberger, 1991), have sometimes ended poorly. If the use of aptitude tests for college admissions is to be abandoned in the U.S. (which appears to us to be likely), it will be important to critically evaluate the predictive utility and potential for bias of whatever is used in its place. Other developed countries provide alternative models for college admissions (McGrath et al., 2014). For example, while several countries use aptitude tests for college admissions in a way that is like how they are used in the U.S., many other countries do not. Countries with successful admissions systems that do not involve use of standardized entrance tests typically use other objective indicators of academic success such as scores on secondary school leaving exams or performance in specific anchor secondary courses (McGrath et al., 2014). To our knowledge, there is limited use of non-ability personality factors for college admissions beyond what might be inferred from letters of recommendation.

Our results show that individuals with low-average IQs can succeed in college, but they are less likely to do so than their higher-ability peers and their success likely depends on non-ability personality skills and social supports that not everyone with IQs in this range share. Our results are also not a repudiation of researchers who have emphasized the importance of general cognitive ability. Indeed, the most prominent among these (Gottfredson, 1997; Herrnstein & Murray, 1994) have consistently argued that while critical, *g* is not the sole determinant of life success.

7.3. Are the benefits associated with college consistent with a college causal Effect?

While there is a large and generally consistent literature on the social and economic benefits associated with college, whether these benefits are actually caused by college has been difficult to resolve (Card, 2001). This is because the benefits associated with a college degree might actually be the result of the ability and non-ability factors that led to being admitted to college in the first place. Economists have used a range of methodologies to investigate the (causal) returns to education, including the cotwin control (CTC) method used here (Ashenfelter & Krueger, 1994; Stanek et al., 2011). The CTC method seeks to strengthen causal inference by determining whether an association between exposure and outcome exists within MZ twins discordant on exposure (McGue et al., 2010). Because MZ twins effectively have the same genomes and rearing environments, within-MZ comparisons control for confounding due to these factors even though they are not explicitly assessed. Among MZ twins discordant for college completion, we found that the college-educated twin scored higher on all four outcomes, although the difference was small and not statistically significant except for occupational status ($d = 0.54$, 95% CI = 0.36, 72). Our results are, consequently, consistent with (but do not prove) a causal effect of college on occupational attainment, but equivocal for the other three outcomes.

There are two major hypotheses for how college might influence social outcomes like occupation (Caplan, 2018). The human capital hypothesis posits that college fosters the development of skills that contribute to occupational success. The alternative, signaling, hypothesis posits that completing college signals to prospective employers that an individual must have possessed the skills needed to gain admission to and ultimately complete college, but that college does not necessarily foster the development of those skills. Although not resolved here, determining whether college exerts its effects through skill building or credentialing has important implications. For example, if the academic success of low-ability students owes principally to grade inflation, the signaling value of a college degree is likely to erode over time.

7.4. Limitations and summary

There are several limitations to our study worth noting. First, our primary sample, while representative of Minnesota for the birth years sampled, is predominantly of European ancestry. Minnesota also has one of the highest rates of college completion among U.S. states (World Population Review, 2021), and may be non-representative in other ways. Indeed, the frequency of completing college among individuals with low levels of general cognitive ability was higher in our Minnesota sample than in the NLSY97, the latter designed to be representative of the U.S. Consequently, the relevance of our findings for other populations remains to be determined. Second, the social and economic outcomes we investigated might be considered a low bar for assessing the benefits of higher education. We believe it likely that our results would have been different had our focus been on the extremes of intellectual achievement (e.g., patents, scientific publications) shown in previous research to be associated with very high GCA (Park, Lubinski, & Benbow, 2008). Our results may also look quite different in ten years, when the sample reaches their prime career years. Nonetheless, the outcomes we investigated – holding a good job, earning a livable income, financial independence, and being a good citizen – are all outcomes valued by society and by the individuals that comprise it.

Despite these limitations, our study showed that individuals with IQs in a range not typically associated with high educational attainment could in some cases complete college. Importantly, the secular expansion in college attainment appears to be driven in large measure by an increasing number of students with low levels of ability completing college. We found that the strength of the association of college with various social outcomes for individuals with an IQ $\leq$ 90 was neither statistically greater nor less than the college effect for higher-ability groups. That is, the low GCA group appeared to benefit from college to the same degree as the other ability groups. The academic success of individuals low in GCA likely owed to a combination of personality and family background factors, only some of which were assessed in our study. Future research should seek to understand the multitude of factors contributing to the academic, economic, and social success of individuals with low-average levels of GCA. They represent a sizable and under-researched segment of the population that our study suggests can enjoy success in multiple life domains given the right circumstances (Murray, 2012).

Open data

Anonymized MTFS participant data is available on the Open Science Framework at https://osf.io/uj9r2/files/?view_only=3071b1bbf15044f3acfc643b5a14f277 Code not available.

Acknowledgement

Research supported by grants from the U.S. National Institute on Alcohol Abuse and Alcoholism (AA09367, AA11886), the National Institute of Mental Health (MH066140), and the National Institute on Drug Abuse (DA05147, DA013240). We thank two anonymous reviewers of an earlier version of this paper for their many helpful comments.

Appendix A. Supplementary Online Material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.intell.2022.101642.

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