European Journal of Personality, *Eur. J. Pers.* **33**: 317–336 (2019)
Published online 9 May 2019 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/per.2202

Genetic and Environmental Influences on Achievement Goal Orientations Shift with Age

ANQING ZHENG[1]*, DANIEL A. BRILEY[1], MARGHERITA MALANCHINI[2], JENNIFER L. TACKETT[3], K. PAIGE HARDEN[2] and ELLIOT M. TUCKER-DROB[2]

[1]*Department of Psychology, University of Illinois at Urbana-Champaign, Champaign, IL USA*
[2]*Department of Psychology and Population Research Center, University of Texas at Austin, Austin, TX USA*
[3]*Department of Psychology, Northwestern University, Evanston, IL USA*

Abstract: Students engage in learning activities with different achievement goal orientations. Some students pursue learning for learning sake (i.e. mastery goal orientation), some are driven by gaining favourable judgement of their performance (i.e. performance approach goal orientation), and others focus on avoiding negative judgement (i.e. performance avoidance goal orientation). These goal orientations are linked with academic achievement, and troublingly, students report decreasing levels of goal orientations across the school years. However, little is known concerning the mechanisms that drive this decline. In a large (N = 891 twin pairs) cross-sectional genetically informative sample (age = 8 to 22 years), we found that older students reported lower goal orientations. Then, we identified shifts in the magnitude of genetic and environmental variance in each goal orientation. For example, variance in mastery goal orientation was primarily associated with environmental factors during the elementary school years. As students entered high school, genetic influences increased, replacing shared environmental influences. Finally, we situated these findings in the larger nomological network by testing associations with psychological constructs (e.g. personality and cognitive ability) and contextual variables (e.g. parents, schools, and peers). The development of academic motivation is complex with many interconnecting factors that appear to shift with age © 2019 European Association of Personality Psychology

Key words: achievement goal orientation; behaviour genetics; academic motivation; conscientiousness; gene × development interaction

Motivational factors are critical in the learning process. Achievement goal orientations refer to a set of constructs that identify sources of motivation for gaining or demonstrating competence. Students vary in their achievement goal orientations to pursue learning for learning's sake (i.e. mastery goal orientation), to pursue learning to do well on exams (i.e. performance approach goal orientation), and to prevent showing incompetence on tasks to other students (i.e. performance avoidance goal orientation). Goal orientation plays an important role in predicting academic outcomes (Hsieh, Sullivan, & Guerra, 2007; Van Yperen, Blaga, & Postmes, 2014). Specifically, both mastery and performance approach goal orientations are positively associated with academic performance (Harackiewicz, Barron, Tauer, & Elliot, 2002; Pintrich & De Groot, 1990), whereas performance avoidance goal orientations are negatively associated with performance (Van Yperen et al., 2014). Maintaining academic motivation is a critical ingredient to avoid high school dropout (Anderson, Hamilton, & Hattie, 2004), an outcome with substantial social, economic, and health ramifications (Rumberger, 1987). However, longitudinal studies have found that the endorsement of both mastery and performance approach goal orientations declines substantially across the school years (Bong, 2001; Pintrich, 2000). This declining trajectory could negatively influence task-related values (Bong, 2001), interests (Harackiewicz et al., 2002), and academic achievement (Church, Elliot, & Gable, 2001; Pintrich, 2000).

To explain these developmental trends, past work has focused on possible psychological (e.g. personality and cognitive ability) and contextual (e.g. classroom goal structure, perceived parental goal orientation, and peer relationships; Anderman & Anderman, 1999; Anderman & Midgley, 1997) variables. These studies emphasize the shifting exposure to social and educational experience that students undertake as they move through schooling. At the same time, academic motivation is known to be influenced by genetic factors (Kovas et al., 2015), and the magnitude of genetic and environmental influences on academically relevant characteristics also shifts across childhood and adolescence (Tucker-Drob, Briley, & Harden, 2013; Tucker-Drob &

*Correspondence to: Anqing Zheng, Department of Psychology, University of Illinois at Urbana-Champaign, 603 E. Daniel Street, Champaign, IL 6182, USA.
E-mail: anqingz2@illinois.edu

This article earned Open Materials badge through Open Practices Disclosure from the Center for Open Science: https://osf.io/tvyxz/wiki. The materials are permanently and openly accessible at https://osf.io/zjgu6. Author's disclosure form may also be found at the Supporting Information in the online version.

Handling editor: Cornelia Wrzus
Received 24 August 2018
Revised 16 March 2019, Accepted 19 March 2019

Harden, 2017). Students may largely adopt the goal structure of their classroom environment in elementary school, but with growing maturity, students may express mastery goal orientations more in line with their genetically influenced characteristics. For example, a high schooler may express mastery goal orientation more in line with their level of openness to experience rather than their teacher's preferences. Behaviour genetic studies can identify whether the magnitude of genetic and environmental influences on achievement goal orientations also shifts across development in tandem with mean-level shifts. Here, we test this question in a large cross-sectional twin sample (N = 891 pairs) by tracking age-related shifts in achievement goal orientations and whether the observed age trends are accompanied by shifts in the magnitude of genetic and environmental influences on achievement goal orientations. By identifying whether genetic and environmental sources of variance shift with age, insight can be gained into the plausible mechanisms of declining academic motivation across childhood and adolescence.

MASTERY AND PERFORMANCE DOMAINS OF ACHIEVEMENT GOAL ORIENTATIONS

Studies on achievement goal orientations traditionally focused on two types of goal orientations: mastery and performance goals (Dweck, 1986). Mastery goal orientation focuses on the learning *process* and mastering tasks, while performance goal orientation focuses on learning *outcomes* and demonstrating competence (Elliot & McGregor, 2001). These two goal orientations represent distinct perceptual-cognitive frameworks in achievement settings, which in turn lead to different patterns of behaviours. A student with a strong mastery goal orientation would seek to learn material fully for the sake of understanding the material, an intrinsic source of motivation. A student with a strong performance goal orientation would seek to learn material in order to perform well on a test and receive recognition from others, an extrinsic source of motivation. These goal orientations are not mutually exclusive. An individual student could report strong mastery and performance goal orientations.

Elliot and Harackiewicz (1996) expanded this dichotomous scheme into a trichotomous version by differentiating performance goal orientations into approach and avoidance dimensions. Under this framework, performance approach largely retains the original definition of performance goal orientations (i.e. the desire to demonstrate ability, outperform others, and obtain success), whereas performance avoidance reflects the desire to avoid appearing incompetent. For example, students with strong performance avoidance goal orientations might avoid raising their hand in class or performing other sorts of visible actions that could be judged by teachers or other students.

This framework has also been extended to a 2 × 2 achievement goal orientation framework that further separates mastery goal orientation into similar approach and avoidance dimensions, where the mastery avoidance goal orientations represent the desire to avoid not mastering the task (Elliot & McGregor, 2001). Huang (2012) meta-analysed 151 studies and found good evidence of discriminant validity, as the mean correlations among achievement goal orientations ranged from .07 to .13. These meta-analytic results imply that achievement goal orientations are not mutually exclusive. In fact, roughly as many students hold consistent achievement goal orientations across mastery and performance goal orientations (i.e. high or low on both) as hold inconsistent goal orientations (i.e. high on one and low on the other).

In this study, we use the trichotomous taxonomy to frame children's achievement goal orientations, in line with a variety of other research (Bong, 2001; Fryer & Elliot, 2007; Meece & Miller, 2001; Pajares & Cheong, 2003). Our measure of achievement goal orientations was drawn from the Patterns of Adaptive Learning Scales (PALS; Midgley et al., 2000). A key advantage of PALS is that the achievement goal measures are embedded with many other contextual factors associated with learning. We used portions of this larger inventory to assess student, perceived parental, and teachers' achievement goals parent, and teacher achievement goals in a manner that has been psychometrically validated (Midgley et al., 2000). However, we cannot distinguish between mastery approach and avoidance achievement orientation goals.

ACHIEVEMENT GOAL ORIENTATION DEVELOPMENT THROUGH CHILDHOOD AND ADOLESCENT

Development of students' goal orientations may occur across childhood and adolescence as individuals explore new social roles and begin making major life decisions related to higher education or occupations. Here, we review evidence on two types of goal orientation change: rank-order stability (Anderman & Midgley, 1997) and mean-level change (Anderman & Anderman, 1999; Bong, 2001) of achievement goal orientations across age and during educational transitions.

Rank-order stability

Rank-order stability (or rank-order consistency) refers to the within-group maintenance of an individual's rank ordering on trait dimensions over time. For example, do individuals that tend to report relatively high levels of mastery goal orientation at age 8 years also report relatively high levels at age 10 years? Empirical studies have found that the rank-order stability of child goal orientations is moderate to high (Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2007). For example, Anderman and Anderman (1999) found a sizable test–retest correlation of mastery goal orientations (r = .57) and performance goal orientations (r = .55) after the transition from elementary school to middle school. In a college sample, Senko and Harackiewicz (2005) found test–retest correlations of mastery and performance goal orientations across one semester to be .66 and .60, respectively. This level of stability places achievement goal orientations alongside other psychological traits in this age range, such as dimensions of personality and cognitive ability (Briley & Tucker-Drob, 2014; Deary, Whalley, Lemmon, Crawford, & Starr, 2000; Rieger et al., 2017; Tucker-Drob & Briley, 2014).

DOI: 10.1002/per

Mean-level change

Mean-level change refers to the extent to which a group of individuals tend to increase or decrease on some variable across time. For example, are mean levels of mastery goal orientation higher at earlier ages compared with later ages? Longitudinal studies tend to find that as students age, endorsement of mastery goal orientation decreases. For example, Meece and Miller (2001) tracked the development of mastery goal orientations from grade 3 to grade 5 and found a decrease of $d = -0.58$. Obach (2003) followed students across grades 6 to 8 and found a continued decline ($d = -0.30$; see also Shim, Ryan, & Anderson, 2008). In a cross-sectional sample, Bong (2001) found a remarkably similar difference between the mastery goal orientation endorsement of elementary students and the mastery goal orientation endorsement of middle schoolers ($d = -0.94$), an effect size almost identical to the combined trend of the longitudinal studies. Mastery goal orientation continues a relatively linear downward trajectory across the high school (Chouinard & Roy, 2008) and college (Fryer & Elliot, 2007) years. In contrast, the pattern of mean-level changes in performance goal orientations is less consistent, with some studies showing mean-level decrease (Anderman & Anderman, 1999; Bong, 2001), whereas other studies show relatively little mean-level change (Anderman & Midgley, 1997). Some of this inconsistency may be due to differing approach and avoid definitions for performance goal orientations. When specifically analysing performance approach goal orientations, which may be potentially adaptive, trends in mastery and performance approach goal orientations both decrease similarly (Schwinger, Steinmayr, & Spinath, 2016).

Mean-level change is also a well-studied aspect of lifespan development in personality traits and cognitive ability (Roberts, Walton, & Viechtbauer, 2006; Tucker-Drob, 2009). Personality dimensions generally trend towards a mature personality profile, meaning individuals tend to become more agreeable, conscientious, and emotional stable over the lifespan (Roberts et al., 2006). Cognitive abilities increase dramatically across the academic years before age 20 years (Tucker-Drob, 2009). Both trends point towards generally positive developmental trajectories. However, personality maturation appears to dip during late childhood and adolescence, especially for conscientiousness, agreeableness, and openness (Soto & Tackett, 2015). This deviation from the maturation trend is referred to as the disruption hypothesis, suggesting that the transition from childhood to adolescence may be accompanied by temporary stressors of development (e.g. puberty and social role transitions) that may interfere with general social pushes towards mature personality profiles. This trend may also be relevant for negative trends in academic motivation. For example, students may not find mastery goal orientation useful when transitioning to an increasingly controlling school environment or when beginning to invest more heavily in social or romantic relationships. Similarly, students may increasingly experience the adverse performance goal orientation consequences because of the stresses of more strenuous testing and workload (Gottfried, Fleming, & Gottfried, 2001).

CONTEXTUAL CORRELATES OF ACHIEVEMENT GOAL ORIENTATIONS

Achievement goal orientations are somewhat stable individual differences that shift across development. This trend implies that there may be differing contextual factors that influence academic goal orientations at different ages (Button, Mathieu, & Zajac, 1996). In particular, students may be socialized to have certain achievement goal orientations by their teachers, parents, and peers.

Perceived goal orientations

Students likely build their schemas concerning achievement goal orientations based on their perception of the valued goal orientations in their environment (e.g. classroom or family; Meece, Anderman, & Anderman, 2006). Classroom or school goal structure is a strong correlate of personal goal orientations (Anderman & Anderman, 1999; Kaplan & Midgley, 1999). School goal structure refers to the school atmosphere, which then sets the norm for classroom goal structure and individual achievement goal orientations. Goal structure could be emphasized by the types of tasks assigned, instructional practices, or the framing of feedback by teachers (Meece et al., 2006). Mastery goal structure is implied by an environment where the norm is learning for the sake of learning. In contrast, a performance goal structure reflects norms that grades, rewards, competition, and showing competence are important. When teachers emphasize improvement, effort, and learning, which would require a mastery goal structure, students are more likely to adopt mastery goal orientations and less likely to focus on performance avoidance goal orientations (Wolters, 2004). The case for performance approach structure is more complex, with both null (Midgley, Kaplan, & Middleton, 2001) and positive (Anderman & Anderman, 1999) associations found between school and individual goal structures. When students perceive their school goal structures as performance approach, students also tend to endorse performance avoidance goal orientations (Wolters, 2004).

As children transition to more advanced grades, teachers tend to emphasize mastery goal orientations less (Anderman & Midgley, 1997; Murayama & Elliot, 2009). If students reflect the goal structure of their environment, then this may account for the trend of declining mastery goal orientations with age. Students may become less motivated academically because of the increasing emphasis on grade point averages and standardized testing that have clear performance goal orientations but less clear mastery goal orientations.

Perceived parental goal structure may also play an important role in children's adoption of personal goal orientations. Students perceive their parents' mastery and performance goal orientations (Friedel, Cortina, Turner, & Midgley, 2007; Gonida, Voulala, & Kiosseoglou, 2009). Perceived parent goal structures are similar to school goal structures. When children perceive their parents endorse a mastery goal orientation, children tend to adopt mastery goal orientations more and have fewer avoidance behaviours in the classroom; when children perceive performance parental goal

DOI: 10.1002/per

orientation, they tend to adopt performance goal orientations and display more avoidance behaviours during school (Friedel et al., 2007). However, as children spend more and more time at school, the effect of parental goal structures may weaken as parents have less time and fewer opportunities to emphasize their expectation.

Importantly, we emphasize *perceived* goal structure in this section. Perceptions of goal structure are conceptually and empirically (Deemer, 2004) distinct from goal structure endorsement by teachers or parents. Put differently, teachers may claim that their classroom uses a mastery goal orientation structure, but students may perceive that performance goal orientations are encouraged. Teachers and students may attend to different situations (e.g. free discussion versus testing), leading to discrepancies between teacher endorsement and student perception. Although the 'true' endorsement by teachers and parents likely matters for student socialization, student perceptions tend to play a larger role in student motivation (e.g. Schiefele & Schaffner, 2015).

Peer relationships

Peer relationships may also influence children's endorsement of achievement goal orientations (Roseth, Johnson, & Johns, 2008). Children who possess positive peer relationships, such as feeling accepted by their peers, may view their classmates as supportive and their classroom as comfortable, which in turn may make them more likely to focus on learning and improvement, rather than worrying about social problems (Urdan, 1997). When children fail to build close peer relationships or negatively experience the social status hierarchy at school, they may engage in more social comparison and competition under the pressure of maintaining and promoting status, which could lead to engagement in academic comparison and competition, thus provoking higher probability to endorse in performance goal orientations (Nelson & Debacker, 2008).

PSYCHOLOGICAL CORRELATES OF ACHIEVEMENT GOAL ORIENTATIONS

Student achievement goal orientations may be informed by psychological characteristics, particularly characteristics related to achievement (Poropat, 2009; Strenze, 2007). Differential psychology has largely focused on cognitive ability and personality dimensions, such as conscientiousness and openness to experience, as predictors of academic achievement.

Cognitive ability

Cognitive ability is strongly correlated with achievement (Strenze, 2007). However, cognitive ability does not appear to be strongly correlated with achievement goal orientations (Eison, 1981; Payne, Youngcourt, & Beaubien, 2007). Payne et al. (2007) report meta-analytic correlations of .04, −.02, and −.09 between cognitive ability and mastery, performance approach, and performance avoidance, respectively.

Personality

Personality dimensions, the relatively enduring patterns of thinking, feeling, and behaving, may also relate to the development of achievement goal orientations. The Big Five (i.e. extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience; John, Naumann, & Soto, 2008) is related to a wide range of academic behaviours including academic achievement and goal orientation (Komarraju, Karau, & Schmeck, 2009; O'Connor & Paunonen, 2007; Poropat, 2009). Within this framework, conscientiousness (primarily associated with effort) and openness (associated with motivation to pursue interests) tend to share variance with achievement goal orientations (Komarraju & Karau, 2005). Specifically, conscientiousness is positively associated with performance approach goal orientation and negatively associated with performance avoidance goal orientation, and openness is positively associated with mastery goal orientation and negatively associated with performance avoidance goal orientation (Briley & Tucker-Drob, 2014; Komarraju & Karau, 2005; Tucker-Drob, Briley, Engelhardt, Mann, & Harden, 2016).

To the extent that students increasingly engage in education in ways that match their personality with age, conscientiousness and openness may become more strongly tied to achievement goal orientations. For example, elementary students may simply take on the achievement orientations instilled by their parents or teachers. High school students may be less interested in following the instructions of their parents or teachers and instead pursue achievement based on their personality. Some students, such as those high in openness, may still seek learning for the sake of learning, but others with different characteristics may not.

DEVELOPMENTAL BEHAVIOUR GENETICS OF ACHIEVEMENT GOAL ORIENTATIONS IN CHILDHOOD AND ADOLESCENCE

Prominent theoretic frameworks (e.g. Eccles & Wigfield, 2002) concerning achievement goal orientations from educational and developmental psychology tend to attribute individual differences and empirical results, such as mean-level change, to environmental experiences. Much work in developmental behaviour genetics emphasizes how environmental experiences are not randomly distributed (Kendler & Baker, 2007) or equally impactful for all individuals (Manuck & McCaffery, 2014). Rather, genetic and environmental influences may become interdependent and transact across development (Bleidorn, Kandler, & Caspi, 2014; Bronfenbrenner & Ceci, 1994; Dickens & Flynn, 2001; Johnson, 2007; Plomin, DeFries, & Loehlin, 1977; Tucker-Drob & Briley, 2019). In addition to additive effects of genetic and environmental influences, genetic and environmental influences could also operate synergistically to guide development (i.e. gene–environment interplay). Such processes could lead to shifts in the magnitude of genetic and environmental influences on phenotypes (i.e. observed psychological

DOI: 10.1002/per

characteristics). Identifying these shifts provides insights into the potential underlying developmental mechanisms at work.

Behaviour genetic studies typically decompose variance in a phenotype into additive genetic (A), shared environmental (C), and nonshared environmental (E) variance components. The classical twin design (Neale & Cardon, 1992) accomplishes this goal by leveraging the differences in genetic relatedness and phenotypic similarity across identical twins (i.e. monozygotic, MZ, sharing 100% of segregating genetic material) and fraternal twins (i.e. dizygotic, DZ, sharing 50% of segregating genetic material on average). Additive genetic influences index the extent to which genetic relatedness is associated with psychological similarity. If more genetically related individuals are also more psychologically similar, then it implies that genetic influences play some role. Identical twins tend to be more similar to one another than fraternal twins are to one another because of genetic influences. Shared environmental influences index the extent to which individuals from the same rearing environment are more similar to one other, regardless of genetic relatedness. Finally, nonshared environmental influences index all effects that would differentiate individuals from the same rearing environment, such as measurement error, unique life experiences, person-specific interpretations of the environmental context, individual relationships with teachers, parents or peers, and all other sorts of idiosyncratic inputs.

Few studies have examined genetic influences on child mastery and performance goal orientations. Tucker-Drob et al. (2016) found that among third to eighth grade children, genetic influences accounted for approximately 20% of the variance in mastery goal orientation, with most of the remaining variance attributable to the nonshared environment. To date, there have been no tests of whether the magnitude of genetic and environmental influences on achievement goal orientations remains constant across development. Many phenotypes do show signs of shifting heritability with age (Bergen, Gardner, & Kendler, 2007; Briley & Tucker-Drob, 2013; Kandler & Papendick, 2017), and these changes tend to be most pronounced during periods of developmental change that co-occur with educational transitions.

As students mature, they may exert more of their own preferences and desires on their achievement goal orientations compared with influences from parents and teachers. To the extent that children's preferences and desires are more genetically influenced compared with the reaction elicited by their environment (e.g. Ayoub et al., 2018), students exerting their preferences could lead to increases in heritability. Increasing heritability may potentially occur simultaneously with decreases in the shared environment as parents' ability to instil similarity loses strength. Parents may still play an influential role, but perhaps parents tailor individualized strategies for each child, reflecting a nonshared environmental influence. Similarly, students may increasingly choose peer groups, classroom experiences, or extracurricular activities that match their level of mastery or performance goal orientation. These experiences may in turn reinforce achievement goal orientations. Again, this process would lead to increasing heritability to the extent that the characteristics that lead students to the experiences are partially heritable. However, it may also be the case that such developmental trajectories are not associated with genetically influenced characteristics but rather with the random churn of high school. Under this scenario, it is more likely that variance would be attributed to the nonshared environment.

Of course, it is also possible that there are no strong age trends in genetic and environmental influences. Further, there is no logical or necessary connection between mean-level trends in achievement goal orientations and shifts in genetic and environmental variance. The variance structure could remain identical even though students tend to decrease in average levels. This result may be most likely if the developmental inputs into achievement goal orientations remain fairly constant across schooling. To the extent that novel mechanisms, such as peer pressure, puberty, or college preparation, play a role in the development of achievement goal orientations, it may be more likely that these mechanisms may draw on systems reflecting different blends of genetic and environmental influences.

THE CURRENT STUDY

Here, we examine age trends in mean levels and genetic and environmental sources of variance for mastery, performance approach, and performance avoidance goal orientations across late childhood and adolescence (ages 8 to 18 years) in a cross-sectional, ethnically and socioeconomically diverse, population-based sample of twin pairs (Harden, Tucker-Drob, & Tackett, 2013). We evaluate whether the established mean-level shifts in achievement goal orientations are accompanied by shifts in the magnitude of genetic and environmental influences. Identifying whether genetic or environmental influences increase or decrease as mean-level shift may provide some insight into the underlying mechanisms that drive the development of achievement goal orientations. Additionally, we situate the achievement goal orientations in the context of other variables that may be related to academic motivation, namely, perceived school goal structure, perceived parental goal structure, peer relationship quality, cognitive ability, conscientiousness, and openness.

METHOD

Participants

All 1935 subjects were drawn from the Texas Twin Project (Harden et al., 2013) who participated in an ongoing project centred in Austin, Texas. Participants were ethnically and socioeconomically diverse. The sample consisted of 891 twin and triplet pairs. Age ranged from 7.80 to 21.29 years (M = 12.22, SD = 2.65), with over 94% of participants between ages 8 and 18 years. Participants were recruited from over 100 schools, with all twin pairs attending the same school. Typically, twins attend the same school but have separate schedules (e.g. Tully et al., 2004). We did not have access to participant's schedules for the current study. The sampling frame was based on recruiting from grades 3 to

DOI: 10.1002/per

12 in the US system, with the relatively few participants over 18 years old having recently completed high school or been held back across grades. The age of the participants was relatively uniformly distributed across ages 8 to 18 years, followed by a precipitous drop above age 18 years (Figure S1). We included the full sample for all analyses with one exception. A total of 37 participants (1.8%) were missing age information and were therefore omitted from models examining age moderation. We focused our primary interpretation in reference to ages 8 to 18 years in order to not extrapolate beyond the data. Data were sparse above age 18 years. Only 5.2% of the sample had an age outside this range, meaning precision for such estimates would be low. The full sample was 53.23% female and was composed of 393 Hispanic, 129 Black, 151 Other race/ethnicity, and 1262 non-Hispanic White participants.

Measures

Measures included zygosity, achievement goal orientation, and several variables that potentially correlate with achievement goal orientations. As shown in Table 1, sample size for individual measures ranged from $N = 1874$ (personality traits) to $N = 545$ (peer relationships). Missing data occurred primarily because of different data collection priorities across subprojects of the Texas Twin Project that led to differential selection of measures across branches of the study. Initial data collection efforts for the Project involved mailed surveys, allowing for more scales (e.g. parent and school goal structure and peer relationships). Subsequent data collection efforts involved in-laboratory assessments, allowing for in-person assessments of cognitive ability, but with reduced survey material. We made use of all available participants. Table 1 also reports relevant psychometric information, such as reliability and unstandardized regression coefficients for age, sex, and age × sex.

Zygosity

Zygosity for same-sex twins was based on parent and examiner responses to survey items regarding the similarity of a number of physical characteristics (e.g. hair texture) and the frequency with which the twins would be mistaken for each other. This method has been validated by comparison with genotyping, with over 99% accuracy (Heath et al., 2003). The sample consisted of 891 pairs of twins: 291 pairs (32.7%) of MZ twins, 310 pairs (34.8%) of same-sex DZ twins, and 290 pairs (32.5%) of opposite-sex twins (DZ).

Achievement goal orientation

Student mastery, performance approach, and performance avoidance goal orientations were measured using three subscales from the PALS (Midgley et al., 2000). Both mastery and performance approach goal orientation scales include five items, and the performance avoidance goal orientation scale has four items. Example items for each of the scales include 'One of my goal orientations in class is to learn as much as I can', 'One of my goal orientations is to show others that I'm good at my class work', and 'It's important to me that I don't look stupid in class'. Participants

Table 1. Descriptive statistics for study outcomes and relations to age and sex

			Twin pair			Unstandardized coefficients		
Outcome variable	No. of items	Sample size	MZ	DZ	Internal consistency	Age	Sex	Age × Sex
Mastery	5	1862	287	557	0.83	−.051 (−.075,−.027)	−.133 (−.231,−.035)	−.026 (−.063,.011)
Performance approach	5	1862	287	557	0.84	−.006 (−.018,.006)	.136 (−.131,.403)	−.003 (−.009,.003)
Performance avoidance	4	1862	287	557	0.56	−.034 (−.059,−.009)	.088 (−.012,.188)	.003 (−.032,.038)
School mastery	6	586	87	171	0.83	−.101 (−.15,−.052)	−.002 (−.184,.180)	−.014 (−.083,.055)
School performance approach	3	585	87	171	0.74	.051 (.004,.098)	.179 (−.062,.420)	−.033 (−.102,.036)
School performance avoidance	5	585	87	171	0.81	.067 (.020,.114)	.220 (.002,.438)	−.040 (−.105,.025)
Parent mastery	6	576	86	171	0.75	−.046 (−.091,−.001)	.027 (−.194,.248)	−.048 (−.117,.021)
Parent performance	5	577	86	171	0.73	.077 (.028,.126)	.505 (.282,.728)	−.056 (−.125,.013)
Peer relationship	26	545	86	168	0.95	−.020 (−.067,.027)	−.084 (−.331,.163)	−.011 (−.084,.062)
Cognitive ability	4	1202	196	399	0.74	.008 (−.008,.024)	.137 (−.132,.406)	.005 (−.005,.015)
Conscientiousness	9	1874	290	573	0.72	−.034 (−.101,.033)	−.158 (−.468,.152)	−.008 (−.024,.008)
Openness	10	1874	290	573	0.73	−.034 (−.059,−.009)	−.158 (−.258,−.058)	−.008 (−.045,.029)

Note: MZ, monozygotic twin; DZ, dizygotic twin. Age was mean centred around 12.22 for all regressions. Sex was coded as 0 = female and 1 = male. Age × Sex was the product of centred age and sex. Dependent variables were standardized in reference to the full sample. 95% confidence intervals are presented in parentheses.

DOI: 10.1002/per

responded to the items on a scale that ranged from 1 (not at all true) to 5 (very true).

Perceived school and parent achievement goal structure
Students' perceived school goal structure (mastery, performance approach, and performance avoidance goal structure) and students' perceptions of parent achievement goal structure (mastery and performance goal structure) were measured using five scales from the PALS (Midgley et al., 2000). These scales include six, three, five, six, and five items, respectively. Example items for each of the scales include 'In our school, trying hard is very important', 'In our school, getting good grades is the main goal', 'In our school, it's very important not to look dumb', 'My parents want my work to be challenging for me', and 'My parents think getting the right answers in class is very important'. Participants responded to the items on a scale that ranged from 1 (not at all true) to 5 (very true).

Peer relationships
The perceived peer relationship quality was measured using the 25-item index of peer relations (Hudson, 1990). Example items include 'I get along very well with my peers' and 'My peers are a real source of pleasure to me'. Participants responded to the items on a scale that ranged from 1 (rarely or none of the time) to 5 (most or all of the time).

Cognitive ability
We tested cognitive ability using Matrix Reasoning, Block Design, Vocabulary, and Similarities tests from the Wechsler Abbreviated Scale of Intelligence-II (Wechsler, 2013). We calculated the full-scale intelligence quotient based on published norms from the administration manual.

Big Five personality
The Big Five personality traits were measured using child versions of the Big Five Inventory (John et al., 2008). We focus on conscientiousness and openness because of their previous empirical and logical connection with achievement goal orientations. Conscientiousness refers to the will to achieve and impulse control. Openness refers to the insight of an individual's mental and experiential life. To control for individual response sets, all items were ipsatized based on within-person means and standard deviations following the recommendations of John et al. (2008).

Analytic plan

Our analyses flowed through four primary steps: (i) Replicate previous evidence for age trends in mean levels of achievement goal orientations. (ii) Estimate correlations between goal orientations and the contextual and psychological variables across the age range. (iii) Estimate the magnitude of genetic and environmental influences on achievement goal orientations across the age range. (iv) Estimate the extent to which genetic and environmental influences account for the observed associations between achievement goal orientations and the contextual and psychological variables.

We anticipated the plausibility of nonlinear age trends in mean levels of achievement goal orientations and in the association between achievement goal orientations and the contextual and psychological variables, due in part to the marked transitions that occur across childhood and adolescence. In order to identify such trends, we used local structural equation modelling (LOSEM; Hildebrandt, Lüdtke, Robitzsch, Sommer, & Wilhelm, 2016). LOSEM weights observations near a focal point more heavily than more distant observations to produce a local estimate of model parameters, similar to the more familiar use of locally estimated scatterplot smoothing curves (Cleveland & Devlin, 1988). To identify whether mean levels of mastery goal orientation decrease with age, a model could be estimated locally at age 8 years, where observations with ages near age 8 years would be weighted heavily relative to observations with ages near age 18 years. Then a model could be estimated locally at age 18 years, where observations near age 18 years would be weighted heavily relative to observations near age 8 years. In practice, we estimated age trends continuously from age 8 to 18 years by fitting models at each 0.1 year increment. Importantly, this approach does not require any arbitrary subsetting of the data. Instead, LOSEM makes use of the full dataset for every model. To avoid capitalizing on noise in the data, we used a wide bandwidth parameter (i.e. 4), which implies that each LOSEM model is based on a larger range of the data and therefore the estimates represent more conservative trends.

To investigate the genetic and environmental influences on achievement goal orientations, we used the classical twin design (Neale & Cardon, 1992), which takes advantage of the known genetic similarity of MZ and DZ twins to identify variance attributable to additive genetic influences (A), shared environmental influences (C), and nonshared environmental influences (E).

Next, we estimated parametric (Purcell, 2002) and nonparametric (Briley, Harden, Bates, & Tucker-Drob, 2015) models, which allow the genetic and environmental influences on each achievement goal orientation to differ as a function of our moderator, age. We used LOSEM to flexibly estimate the magnitude genetic and environmental influences as a function of age, and we then tested whether such trends were statistically significant using standard parametric approaches. The parametric approach builds on the classic twin model by allowing the ACE components to differ as a function of a moderator, such as age.

It is possible to conduct hypothesis testing with LOSEM using a permutation testing approach (Hildebrandt et al., 2016, pp. 263–264), but such tests are less powerful than parametric tests (Briley et al., 2015, figure 6). We followed the recommendations of Hildebrandt et al. (2016) to conduct significance tests of whether the parameters of interests varied across the moderator by creating an empirical null distribution with permuted age variables based on randomly shuffling the observed age variable. If variability of the parameter was larger in the observed data than in the random data, this indicates that we can reject the null hypothesis that the trend is flat across the moderator.

DOI: 10.1002/per

Finally, we used bivariate Cholesky models to partition the variance in achievement goal orientation into genetic and environmental variance that is shared with the contextual and psychological variables. Cholesky decompositions are the behaviour genetic analogue of regression and can test whether genetic and environmental influences on one phenotype also contribute to another phenotype. An example of the model can be seen in Figure 1. As shown, A_m and A_p denote the genetic factors of mastery goal orientation and peer relationship quality, C_m and C_p represent the shared environmental factors, and E_m and E_p represent the nonshared environmental factors. The cross-paths estimate the extent to which genetic and environmental influences on peer relationship quality also play a role in mastery goal orientation. For example, the a_{12} pathway estimates the extent to which the genetic influences on peer relationship quality account for variance in mastery goal orientation. The a_{22}, c_{22}, and e_{22} pathways represent the unique ACE variance in mastery not shared with peer relationship quality.

All analyses were conducted with M*plus* using full information maximum-likelihood estimation to account for missing data (Muthén & Muthén, 2017) and the MplusAutomation package in R (Hallquist & Wiley, 2018). All models residualized for age, sex, and age × sex effects (McGue & Bouchard, 1984). We corrected standard errors by using the TYPE = COMPLEX option and the cluster option of M*plus* with the family identifier set as the clustering variable. These commands take into account the nonindependence of observations stemming from including individuals from the same family and for repeated measurements of some participants (McNeish, Stapleton, & Silverman, 2017).

The current analyses were not preregistered. This research should be considered exploratory. Sample size for the current study was based on all available data from the Texas Twin Project, collected over approximately 6 years. All materials and procedures employed in this study are available on Open Science Framework https://osf.io/75gyh/. The data for the current project are not publicly available because of the language of the consent and assent forms agreed to with the parents and participants. For more information about the Texas Twin Project data availability and previous studies, please see http://sites.la.utexas.edu/twinproject/. No previous study has analysed the variables included in this report to answer these questions. We report effect sizes and 95% confidence intervals.

RESULTS

The descriptive statistics, phenotypic correlations, and within-pair twin correlations for all phenotypes are shown in Table 1–2. Zero-order correlations without age and gender residualization returned similar results, which can be found in Table S1. The correlations among the achievement goal orientations ranged from .08 to .56, which is typical in this age range (Elliot & McGregor, 2001). The goal structure children perceived as emphasized in their school and by their parents had the strongest associations with their own corresponding achievement goal orientations (*r*'s ranged from .31 to .45), consistent with past work (Senko, Hulleman, & Harackiewicz, 2011). This result indicates that children possess achievement goal orientations that match their perceived environment. Peer relationship quality, conscientiousness, and openness were positively correlated with mastery and negatively correlated with performance avoidance. These effect sizes were of moderate magnitude. Performance approach was only modestly correlated with these variables. Cognitive ability was not correlated with any goal orientation.

The MZ twin correlations for the achievement goal orientations (r = .29 to .38) were all larger than the DZ twin correlations (r = .06 to .19), suggesting genetic influences. Zero-order twin correlations returned similar results (Table S1). Evidence of shared environmental influence was rare, except for school goal structure for which MZ and DZ twin correlations were similar in magnitude. All variables showed evidence of nonshared environmental effects as MZ correlations were all substantially below 1.

Phenotypic age trends in achievement goal orientations and associations with contextual and psychological variables

Results of mean-level and variance age trends in achievement goal orientations using LOSEM can be found in Figure 2, and

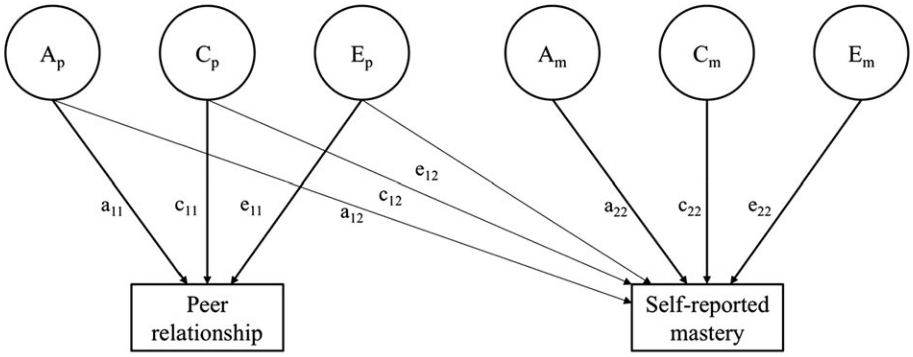

Figure 1. Bivariate Cholesky model used to estimate the additive genetic, shared, and nonshared environmental contributions to the covariance between self-reported mastery and peer relationship. A, additive genetic variance; C, shared environmental variance; E, nonshared environmental variance.

Table 2. Phenotypic correlations and twin correlations

Outcome variable	Partial correlation: Mastery	Partial correlation: Performance approach	Partial correlation: Performance avoidance	Twin correlation: MZ	Twin correlation: DZ
Mastery	—	—	—	.381 (.259,.503)	.194 (.104,.284)
Performance approach	.214 (.165,.263)	—	—	.318 (.208,.428)	.086 (−.008,.180)
Performance avoidance	.081 (.034,.128)	.555 (.500,.610)	—	.291 (.169,.413)	.063 (−.029,.155)
School mastery	.410 (.339,.481)	.125 (.047,.203)	.035 (−.045,.115)	.433 (.225,.641)	.339 (.196,.482)
School performance approach	.120 (.038,.202)	.306 (.228,.384)	.179 (.083,.275)	.373 (.189,.557)	.214 (.067,.361)
School performance avoidance	−.016 (−.090,.058)	.482 (.404,.560)	.449 (.365,.533)	.377 (.199,.555)	.279 (.130,.428)
Parent mastery	.388 (.310,.466)	.197 (.107,.287)	.150 (.060,.240)	.470 (.292,.648)	.196 (.047,.345)
Parent performance	.045 (−.035,.125)	.389 (.305,.473)	.362 (.272,.452)	.406 (.235,.577)	.090 (−.067,.247)
Peer relationship	.264 (.180,.348)	.003 (−.091,.097)	−.161 (−.251,−.071)	.529 (.308,.75)	.084 (−.088,.256)
Cognitive ability	−.003 (−.068,.062)	−.093 (−.154,−.032)	.076 (.013,.139)	.768 (.686,.850)	.410 (.324,.496)
Conscientiousness	.252 (.203,.301)	.021 (−.024,.066)	−.045 (−.090,.00)	.288 (.172,.404)	.082 (−.010,.174)
Openness	.142 (.087,.197)	−.082 (−.127,−.037)	−.015 (−.060,.030)	.344 (.230,.458)	.129 (.037,.221)

Note: All variables have been residualized for age, sex, and age × sex. 95% confidence intervals are presented in parentheses.

the age trends in contextual and psychological correlates are in Figures S2 and S3. We estimated local mean and variance parameters continuously from age 8 to 18 years. Our results replicated previous findings of the declining trend of mean levels of achievement goal orientation. From age 8 to 18 years, mastery goal orientation declined approximately 0.4 *SD*, 0.2 *SD* for performance avoidance goal, and 0.1 *SD* for performance approach goal (shown in Figure 2A). Permutation tests indicated that the mean-level trend was significant for men and women for mastery and performance avoidance goal orientations ($p < .01$) but not for performance approach goal orientation. The variance in mastery goal orientation increased approximately 23.5% relative to age 8 years, decreased 5% for performance approach goal, and decreased 28.6% for performance avoidance goal (Figure 2B). Permutation tests indicated that the variance trend was only significant for performance avoid goal orientation ($p < .01$). LOSEM also identified potential non-linearities in the age trend for mastery, where the increases in age-related differences were mostly concentrated between ages 10 and 16 years.

Additionally, we were interested in whether the contextual and psychological variables differentially correlated with

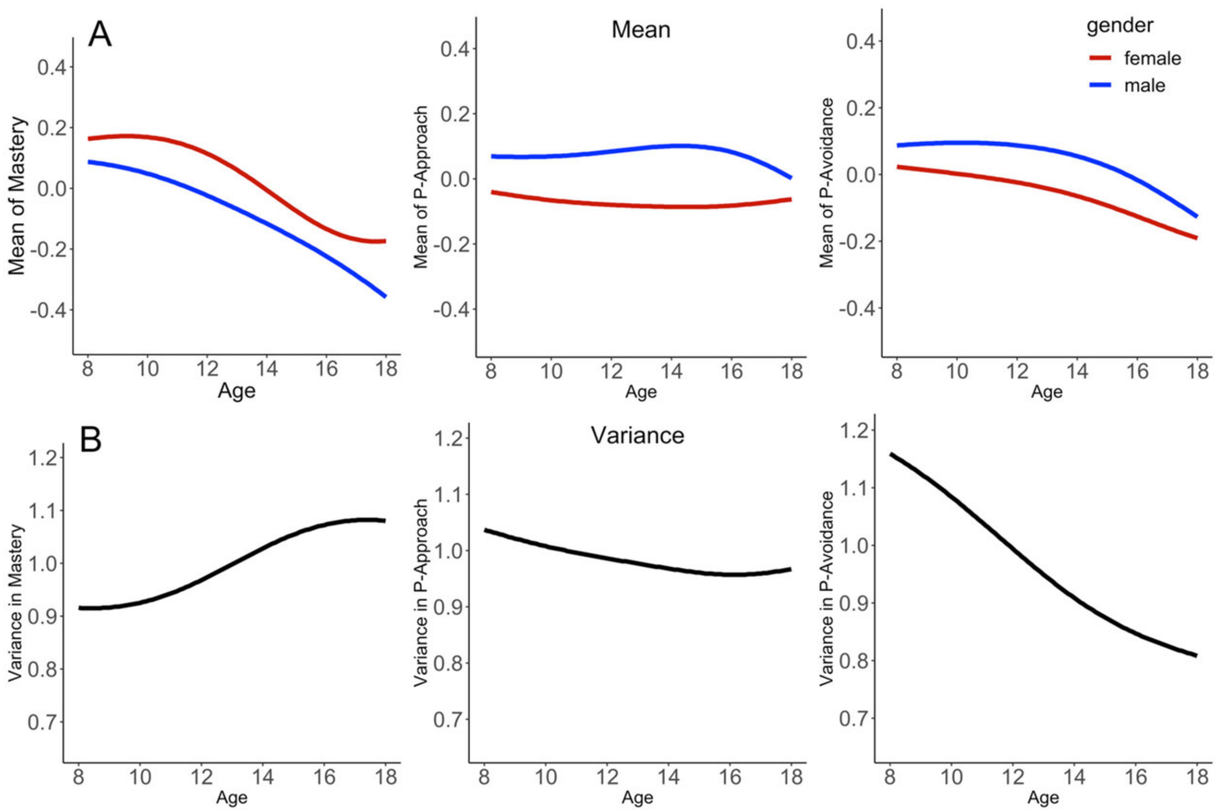

Figure 2. Local structural equation modelling result showing the (A) mean-level age trends and (B) between-person variance for the mastery, performance approach, and performance avoidance goal orientations. Gender differences were minor.

DOI: 10.1002/per

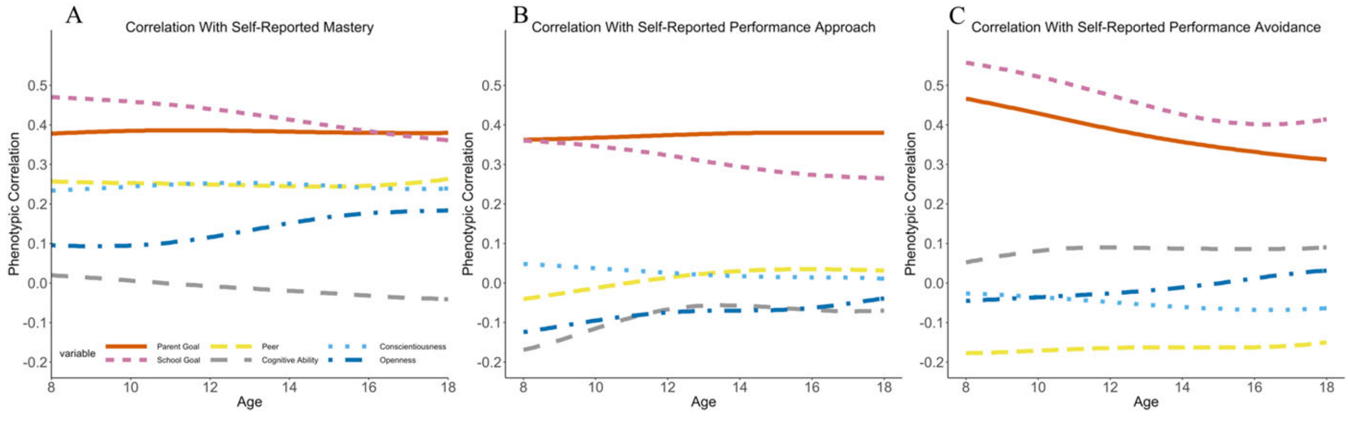

Figure 3. Local structural equation modelling estimated nonparametric age trends in correlations between (A) mastery, (B) performance approach, and (C) performance avoidance goal orientations and corresponding psychological predictors. For parent and school goals, the matching achievement goal orientation is represented in the graph. [Colour figure can be viewed at wileyonlinelibrary.com]

achievement goal orientations across the age range. Using LOSEM, we estimated nonparametric age-related shifts in these associations. Figure 3 displays these results with the *y*-axis representing the correlation between a goal orientation and another variable. Across all three goal orientations, the association with the school goal structure decreased with age. The connection between younger student's goal orientation and their school was stronger compared with older students. For mastery goal orientation, personal characteristics became more important with age. In particular, the association between mastery and openness roughly doubled across this age range. In contrast, neither performance goal orientation was more strongly correlated with personal characteristics at older ages. In fact, the associations between performance approach goal orientation and cognitive ability and openness were largest at early ages and trended towards zero by age 13 years. However, the magnitude of these shifts was rather modest in absolute terms. Overall, the patterns of association between goal orientation and the other included variables were largely consistent across age.[1]

Genetic and environmental influences on achievement goal orientations

Standardized parameter estimates of the ACE model are presented in Table 3. Model fit was generally acceptable, except for perceived school performance approach and perceived school performance avoidance. This poor fit most likely occurred because of somewhat lower opposite-sex DZ twin correlations compared with same-sex DZ twin correlations. Given the relatively small sample size for these measures (256 pairs), we chose to avoid potentially overfitting the data by specifying more complex sex-limitation models. These sorts of models would be underpowered in the current sample. The heritability for self-reported achievement goal orientations ranged from 24% to 33%, with 64% to 76% of variance attributed to the nonshared environment. Among the three self-report goal orientations, only mastery goal orientation showed modest evidence for shared environmental influence. Results were similar for the other variables, with the exception of larger estimates of the shared environment for measures of school goal structure.

Next, we evaluated whether the magnitude of genetic and environmental influences on achievement goal orientations shifts with age using LOSEM. Investigating trends in raw variance is important when there are shifts in total variance, as trends could be masked when taking the proportion of a shifting total variance. As shown in Figure 4,[2] genetic influences on mastery goal orientation were negligible at age 8 years, rose in magnitude until roughly age 15 years, and then fell precipitously afterward ($p = .018$). At the peak level of heritability, genetic influences accounted for approximately 40% of the total variance. This trend was mirrored by larger estimates of the shared environment at younger and older ages. The nonshared environment accounted for a relatively consistent variance. Only the age trend for genetic influences was significant using a permutation test. These results indicate that genetically influenced processes emerge for mastery goal orientation during a time of mean-level decreases, and as students approach the end of high school, family-level processes return to playing a more prominent role. There was no evidence of age trends for performance approach goal orientation. For performance avoidance goal orientation, the trend of decreasing variance with age was driven by decreasing nonshared environmental influences, but genetic and shared environmental sources of variance were essentially flat (Figure 4A). No age trends in genetic or environmental influences for either performance goal orientation were significant using permutation tests.

We used the LOSEM results to guide parametric model specification. Specifically, the standard specification of the moderation model would be unable to capture the inverted-U shape identified for mastery goal orientation

[1]Permutation tests indicated that the age trends were significant for certain pairings: mastery goal orientation with parent mastery goal orientation and peers; performance approach goal orientation with openness and cognitive ability; performance avoid goal orientation with school performance avoid goal orientation, parent performance orientation, and cognitive ability.

[2]Results displaying proportion of genetic and environmental variance showed similar results (see Figure S4).

DOI: 10.1002/per

Table 3. Genetic and environmental proportions of variance

Variable	A^2	C^2	E^2	CFI	TLI	RMSEA	Chi-square
Mastery	.327 (.090,.564)	.036 (−.178,.250)	.637 (.578,.696)	1.000	1.052	0.000	24.574
Performance approach	.274 (.176,.372)	.000—	.726 (.628,.824)	0.817	0.740	0.028	37.913
Performance avoidance	.238 (.175,.301)	.000—	.762 (.699,.825)	1.000	1.033	0.000	29.511
School mastery	.000—	.378 (.302,.454)	.622 (.546,.698)	0.891	0.905	0.006	39.512
School performance approach	.215 (−.216,.646)	.123 (−.214,.460)	.662 (.499,.825)	0.373	0.454	0.064	42.010
School performance avoidance	.153 (−.155,.461)	.209 (.033,.385)	.637 (.186,1.088)	0.562	0.618	0.080	48.261
Parent mastery	.441 (.374,.508)	.000—	.559 (.492,.626)	1.000	1.005	0.000	3.785
Parent performance	.340 (.183,.497)	.000—	.660 (.503,.817)	1.000	1.058	0.000	29.171
Peer relationship	.451 (.365,.537)	.000—	.549 (.463,.635)	0.891	0.905	0.029	33.256
Cognitive ability	.629 (.453,.805)	.113 (−.083,.309)	.259 (.212,.306)	1.000	1.033	0.000	24.095
Conscientiousness	.252 (.191,.313)	.000—	.748 (.687,.809)	0.883	0.898	0.029	38.386
Openness	.320 (.263,.377)	.000—	.680 (.623,.737)	1.000	1.123	0.000	19.263

Note: The effect size estimates reflect the proportion of variance attributable to genetic or environmental sources. A^2, additive genetic variance; C^2, shared environmental variance; E^2, nonshared environmental variance; RMSEA, root mean square error of approximation; CFI, comparative fit index; TLI, Tucker Lewis Index; 95% confidence intervals are presented in parentheses.

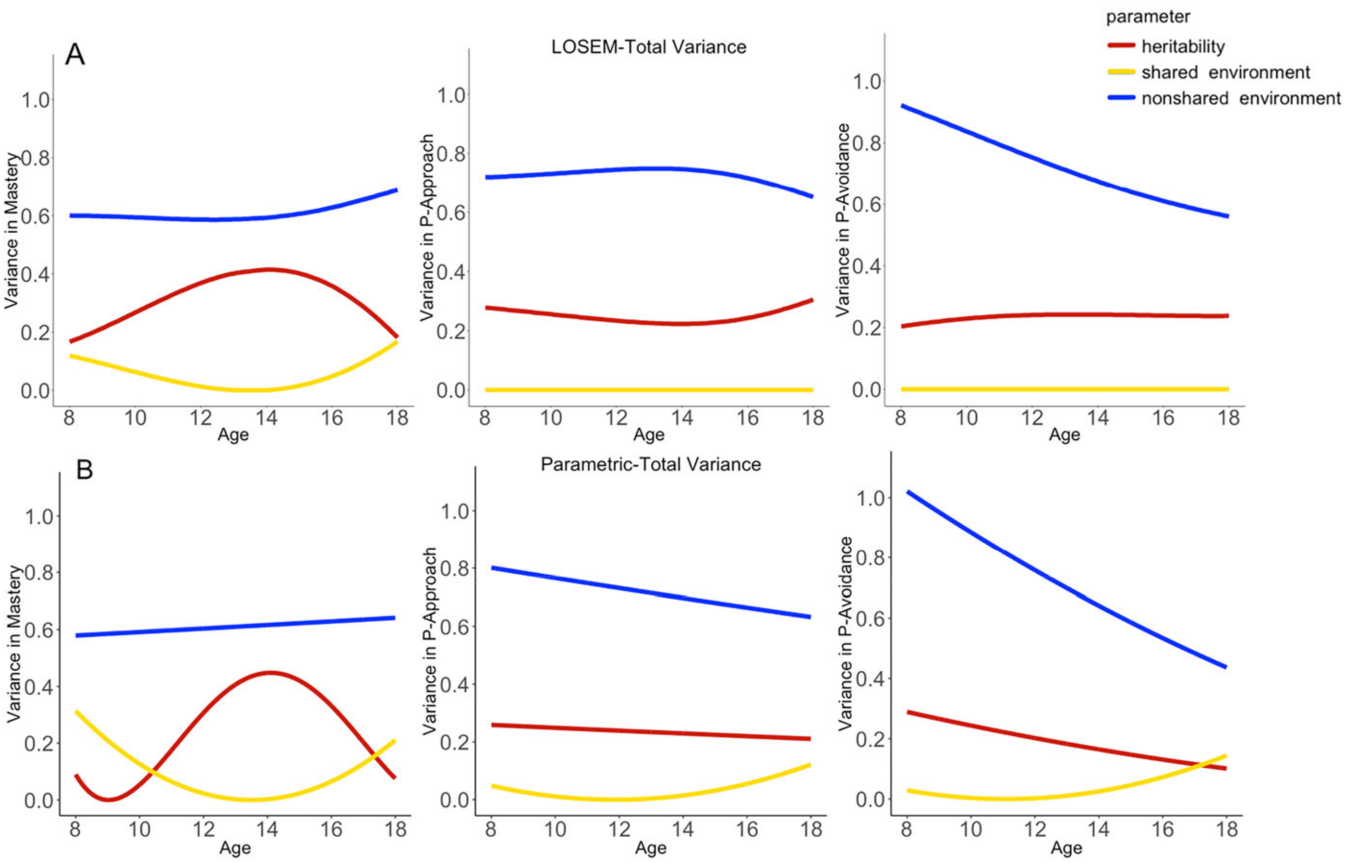

Figure 4. Age trends in total variance composite to genetic and environmental components for mastery, performance approach, and performance avoidance goal orientations using a (A) nonparametric and (B) parametric approach.

(Briley et al., 2015; Purcell, 2002). Therefore, we included a moderation term for age^2 for the genetic function in addition to moderation by age. The age trends in the behaviour genetic parameters of achievement goal orientations are summarized in Table 4 using the parametric approach. The coefficients reflect age trends in genetic and environmental influences on the achievement goal orientations. One can calculate the model-implied genetic variance by inserting a specific age into the formula. The result is squared to produce the expected genetic variance. Because of the need to square the result, coefficients reflecting age trends resemble quadratic trends, and coefficients reflecting age^2 trends resemble cubic trends as they would appear in a standard regression framework.

The results match those found with the nonparametric approach for mastery goal orientation. The inverted-U shape was identified for genetic influences. Genetic influences on mastery goal orientation were estimated to be 0 at age 9 years,

DOI: 10.1002/per

Table 4. Unstandardized parameter estimates for age moderation ACE model

Variable	a	a′	a″	c	c′	e	e′
Mastery	.577 (.454,.700)	.098 (.033,.163)	−.026 (−.048,−.004)	.130 (.003,.257)	−.102 (−.131,−.073)	.778 (.727,.829)	.004 (−.014,.022)
Performance approach	.488 (.370,.606)	−.005 (−.060,.050)	——	.020 (−.135,.175)	.057 (−.002,.116)	.853 (.792,.914)	−.010 (−.035,.015)
Performance avoidance	.445 (.320,.570)	−.022 (−.095,.051)	——	.062 (−.107,.231)	.055 (.014,.096)	.863 (.8,.926)	−.035 (−.057,−.013)

Note: 95% confidence intervals are provided in parentheses. Age was centred at the mean of 12.22 years. a, additive genetic effect; c, shared environmental effect; e, nonshared environmental effect; ′ indicates the age moderation effects for a, c, and e. ″ indicates the age^2 moderation effects for a.

increased to 42% by age 14 years, and then decreased to 8% by age 18 years. The shared environment, on the other hand, accounted for 26%, 0%, and 23% of the variance at each of these ages, respectively. The nonshared environment was estimated to be essentially flat. The parametric results for performance approach and avoid orientations were also similar to the nonparametric approach, with one major exception. The parametric models indicated the possibility for nontrivial (~10% and 25% of the total variance, respectively) shared environmental influences on both approach and avoid performance orientations at older ages, in contrast to the flat shared environmental trends observed in the nonparametric approach. The largest age trend in terms of shifts in variance was the decreasing nonshared environmental influence on performance avoidance (Figure 4B).[3]

Genetic and environmental contributions to the associations between achievement goal orientation and correlated variables

Finally, we partitioned the variance in achievement goal orientations into genetic and environmental variance that is shared with school goal structure, perceived parent goal orientation, peer relationship quality, cognitive ability, conscientiousness, and openness. We were primarily interested in the genetic (a_{12}), shared environmental (c_{12}), and nonshared environmental (e_{12}) cross-pathways. These parameters reflect the extent to which genetic and environmental influences on the contextual and psychological variables are statistically associated with achievement goal orientations. We encountered convergence issues when attempting to estimate the shared environmental associations with achievement goal orientations, most likely because of the finding that none of the achievement goal orientations possessed meaningful shared environmental variance (<4% of the total variance). Most often the best fitting model would produce a large estimate for the shared environmental cross-path (c_{12}) but a near-zero estimate for the shared environmental variance of the predictor variable (c_{11}). For example, the model for cognitive ability estimated a sizeable and statistically significant shared environmental cross-pathway but no shared environmental variance for cognitive ability. These parameter estimates are implausible. Therefore, we fixed to zero the shared environmental cross-pathway for all models, which produced sensible estimates.

Table 5 presents the path coefficients from the bivariate analyses. The first three columns give the proportion of variance due to genetic and environmental factors for the contextual and psychological predictors. The next two columns give the genetic (a_{12}) and nonshared environmental (e_{12}) cross-pathways. These parameters can be interpreted analogous to standardized regression coefficients. The final three columns give the *residual* proportions of genetic and environmental variance for the achievement goal orientations.

[3]Significance tests for the parametric approach, which are more powerful than the nonparametric tests, indicated significant moderation for mastery goal orientation genetic and shared environmental influences, as well as performance avoid goal orientation shared and nonshared environmental influences.

DOI: 10.1002/per

Table 5. Cholesky decomposition of relations between psychological correlates and goal orientations

	a_{11}^2	c_{11}^2	e_{11}^2	a_{12}	e_{12}	a_{22}^2	c_{22}^2	e_{22}^2
Mastery								
Perceived school mastery	.139 (−.306,.584)	.259 (−.096,.614)	.602 (.433,.771)	.490 (−.329,1.309)	.291 (.171,.411)	.154 (−.552,.860)	.000—	.551 (.502,.600)
Perceived parent mastery	.428 (.271,.585)	.000—	.572 (.415,.729)	.361 (.200,.522)	.204 (.073,.335)	.217 (.029,.405)	.029 (−.161,.219)	.596 (.288,.904)
Peer relationship	.448 (.211,.685)	.000—	.552 (.315,.789)	.174 (.019,.329)	.186 (.057,.315)	.334 (.058,.610)	.006 (−.200,.212)	.596 (.484,.708)
Cognitive ability	.626 (.395,.857)	.115 (−.073,.303)	.260 (.178,.342)	−.046 (−.160,.068)	.070 (−.046,.186)	.323 (.047,.599)	.037 (−.173,.247)	.632 (.526,.738)
Conscientiousness	.249 (.145,.353)	.000—	.751 (.647,.855)	.206 (.051,.361)	.162 (.076,.248)	.331 (.217,.445)	.002 (−.190,.194)	.602 (.343,.861)
Openness	.320 (.224,.416)	.000—	.680 (.584,.776)	.067 (−.064,.198)	.088 (.004,.172)	.331 (.055,.607)	.029 (−.181,.239)	.628 (.522,.734)
Performance approach								
Perceived school performance approach	.209 (−.195,.613)	.127 (−.189,.443)	.664 (.503,.825)	.175 (−.117,.467)	.285 (.142,.428)	.244 (.130,.358)	.000—	.647 (.508,.786)
Perceived parent performance	.337 (.182,.492)	.000—	.663 (.508,.818)	.166 (−.046,.378)	.349 (.224,.474)	.248 (.183,.313)	.000—	.612 (.571,.653)
Peer relationship	.457 (.232,.682)	.000—	.543 (.318,.768)	−.021 (−.215,.173)	.061 (−.113,.235)	.275 (.218,.332)	.000—	.720 (.665,.775)
Cognitive ability	.639 (.398,.880)	.102 (−.092,.296)	.259 (.175,.343)	−.124 (−.247,−.001)	−.004 (−.153,.145)	.255 (.155,.355)	.000—	.730 (.624,.836)
Conscientiousness	.253 (.149,.357)	.000—	.747 (.643,.851)	−.050 (−.187,.087)	.056 (−.026,.138)	.272 (.174,.37)	.000—	.722 (.618,.826)
Openness	.321 (.225,.417)	.000—	.679 (.583,.775)	−.161 (−.29,−.032)	.011 (−.071,.093)	.250 (.183,.317)	.000—	.725 (.670,.780)
Performance avoidance								
Perceived school performance avoidance	.125 (−.010,.260)	.243 (.143,.343)	.632 (.501,.763)	.486 (.392,.580)	.387 (.277,.497)	.000—	.000—	.603 (.562,.644)
Perceived parent performance	.334 (−.083,.751)	.002 (−.302,.306)	.664 (.484,.844)	.143 (−.092,.378)	.368 (.211,.525)	.219 (.152,.286)	.000—	.633 (.549,.717)
Peer relationship	.451 (.224,.678)	.000—	.549 (.322,.776)	−.065 (−.261,.131)	−.196 (−.355,−.037)	.234 (.167,.301)	.000—	.723 (.664,.782)
Cognitive ability	.630 (.401,.859)	.111 (−.075,.297)	.259 (.177,.341)	.075 (−.052,.202)	.043 (−.126,.212)	.235 (.170,.300)	.000—	.758 (.697,.819)
Conscientiousness	.252 (.148,.356)	.000—	.748 (.644,.852)	−.067 (−.204,.070)	−.036 (−.118,.046)	.235 (.172,.298)	.000—	.760 (.697,.823)
Openness	.321 (.225,.417)	.000—	.679 (.583,.775)	−.051 (−.178,.076)	−.003 (−.089,.083)	.236 (.173,.299)	.000—	.761 (.698,.824)

Note: Parameters labelled with *a*, *c*, and *e* reflect genetic, shared environmental, and nonshared environmental variance components. Parameters labelled with the subscript 11 reflect genetic and environmental variance for the psychological or contextual variable. These also carry a superscript of 2 that reflects that these are standardized proportions of variance. Parameters labelled with the subscript of 12 reflect cross-pathways from the predictor variables to the achievement goals. These are interpreted similarly to standardized regression parameters. Parameters labelled with the subscript 22 reflect *residual* genetic and environmental influences on the achievement goals after taking into account the predictor. These values have also been standardized as proportions of variance. 95% confidence intervals are presented in parentheses.

DOI: 10.1002/per

These values do not sum to one because of the cross-pathways that also account for variance in the achievement goal orientations.

For mastery goal orientation, a substantial portion of genetic variance was associated with the perceived parent and school mastery goal structure. However, the estimate was very imprecise for school mastery, most likely because of relatively small sample size. These results imply that genetic influences on student's perception of the environment are shared with their level of mastery goal orientation, perhaps driven by students perceiving environments that match their desired level of mastery. The nonshared environmental pathways were also substantial and much more precisely estimated. These results imply that the identical twin that perceives their parent or school as more mastery focused also tends to have higher levels of mastery goal orientation. The genetic pathways accounted for approximately 18% of the total variance in mastery goal orientation, and the environmental pathways accounted for approximately 6%. Peer relationship quality was also positively associated with mastery goal orientation through both genetic and environmental pathways. The magnitude of these pathways was very similar, each accounting for a little over 3% of the variance in mastery goal orientation. Turning towards the personality dimensions, cognitive ability was not associated with mastery goal orientation. Conscientiousness was positively associated with mastery through both genetic (4%) and environmental (3%) pathways. Openness was primarily associated via an environmental pathway (1%).

Results for performance approach and performance avoidance were largely similar to mastery goal orientation. Parent and school goal structures tended to be associated with student goal orientation through both genetic and environmental pathways. The environmental pathways tended to be stronger compared with the genetic pathways. Peer relationship quality was not associated with performance approach, but relationship quality was associated with performance avoidance through an environmental pathway (4% of the total variance). This result implies that the identical twin that has worse peer relationships also tends to endorse avoidance goal orientations to a greater extent. The personality variables tended to not be associated with either performance goal orientation, with the exception of a small genetically mediated, negative association between approach goal orientation and openness (3% of the total variance).

DISCUSSION

Student academic motivation is critical for successful cognitive growth and scholastic performance. Motivation can be derived from multiple sources and for multiple reasons. We evaluated the development of motivation derived from a desire to obtain or demonstrate competence in relation to psychological (e.g. personality and cognitive ability) and contextual (e.g. parents, schools, and peers) variables. Consistent with past work on motivation (Kovas et al., 2015; Luo, Kovas, Haworth, & Plomin, 2011; Malanchini et al., 2017), we found that genetic and environmental influences are relevant for academic motivation. By identifying these factors across a developmental period of tremendous change for most students, our results point towards potential mechanisms of growth.

Our study replicated previous work (Bong, 2001; Chouinard & Roy, 2008; Fryer & Elliot, 2007; Meece & Miller, 2001; Obach, 2003) demonstrating that mean levels of achievement goal endorsement decrease between ages 8 and 18 years. Students tend to be less academically motivated to pursue learning as an intrinsic goal at older ages. At the same time, the magnitude of individual differences tended to increase for mastery, decrease for performance avoidance, and remain relatively stable for performance approach.

We also examined whether these mean-level and variance shifts were accompanied by shifts in the magnitude of genetic and environmental influences on achievement goal orientations. Genetic and environmental influences on performance approach and avoidance goal orientations were largely consistent across the age range. One exception was that the trend of overall decreasing total variance in performance avoidance goal orientation was driven by decreases in nonshared environmental variance. This result could be due to less measurement error at older ages or fewer individual-level experiences influencing avoidance.

For mastery goal orientation, we found a more complex pattern. Genetic influences on mastery goal orientation were small at early ages, rose fairly quickly until approximately age 15 years, and then plummeted. This period of increase coincides with the typical age of transition to high school, and the period of decrease marks a time during which most students approach graduation and begin considering career paths or college. The shared environment displayed an opposite trend. We contextualized this novel finding with several contextual and psychological variables. Mastery goal orientation was moderately correlated with the perceived goal structure of the child's parents and school, in addition to a modest correlation with openness. We hypothesized that any shifts in variance towards genetic factors would be accompanied by increases in the correlation with personality, and any shifts away from shared environmental factors would be accompanied by decreases in the correlation between mastery and environmental goal structure. We observed this trend for the initial increase in genetic influences up to age 15 years but found no similar evidence for the decrease at older ages (Figure 3). However, these slight shifts only partially explain the observed age trend. Thus, there are several potential explanations for the results we obtained.

Implications of shifting genetic and environmental influences

Multiple developmental mechanisms could result in rapid increases, followed by decreases, in genetic variance for mastery goal orientation. At young ages, individual differences in mastery goal orientation were most strongly associated with the shared and nonshared environment. The shared environment could reflect family-level values that are transmitted to children, including values learned at

DOI: 10.1002/per

school when the children attend the same school. The nonshared environment could reflect individual-level beliefs about learning, perhaps driven by idiosyncratic experiences with teachers, tests, or peers.

Our results are consistent with children increasingly moving away from these environmental sorts of developmental inputs and towards genetically influenced characteristics with age. For example, personality characteristics, such as openness, could become more impactful for achievement goal orientations. Elementary students might express similar mastery goal orientation based on socialized values, but after moving on to high school, students with high levels of openness might represent most students who maintain high levels of mastery. The introduction of novel environmental pressures from school or peers might make personal characteristics more relevant. Under this process, novel forms of genetic influence would become relevant for achievement motivation. We found evidence for this process in that openness was more strongly correlated with mastery at older ages, but this effect was small. Other genetically influenced characteristics that were not measured in this study could play a larger role, or many such characteristics may exert small effects that sum to the relatively large aggregate age trend that was observed.

In contrast, it is possible that existing genetic variance accumulates and increasingly guides development with age. Genetic influences may play a small role in whether students find learning enjoyable at early ages, but these influences remain minor because of the randomness of the school day and the general environmental control exerted by teachers. As students gain more control over their course schedule and peer groups, students with a mastery goal orientation may enrol in more challenging courses or gravitate towards peers with similar outlooks on learning. This process would result in a correlation emerging between early genetic characteristics and environmental experiences (Scarr & McCartney, 1983). Students might evoke a response from teachers or peers based on their genetically influenced characteristics, or they might actively seek out certain environments based on their characteristics. In behaviour genetics, these processes are termed evocative gene–environment correlation and active gene–environment correlation (Plomin et al., 1977). Importantly, even though these mechanisms appear environmentally driven because the environment exerts a causal effect on development, genetic variance increases to the extent that genetically influenced characteristics guide experiences. Gene–environment correlation is a prominent explanation for why many characteristics tend to show increasing genetic variance with age (Bergen et al., 2007; Briley & Tucker-Drob, 2013; Dickens & Flynn, 2001).

We were unable to differentiate between these two possibilities for the rise in genetic variance. This makes straightforward implications for educational interventions difficult. One possibility for the increase in heritability is that genetic effects that are invariant across contexts and environments play an increasing role, suggesting that interventions treating school environments or teacher–student relationship may be less effective. An equally plausible interpretation is that genetically influenced characteristics are associated with the environment, so interventions that enable students to become systematically exposed to certain environments may be efficacious. As an example, we found that perceived parent and school goal structure were the strongest correlates of student achievement goal orientation (likely due, in part, to common method bias). If teachers or parents provide a socialization base for students at early ages (i.e. large shared environmental variance for mastery goal orientation), the results imply that students perceive teachers and parents as increasingly displaying achievement goal orientations more in line with their genetically influenced characteristics (i.e. shared environmental variance near zero and large genetic variance). This process may be advantageous, showing that parents and teachers are responsive to the needs of the student. Alternatively, it may be the case that this trend reflects maladaptive behavioural patterns whereby teachers and parents recalibrate their expectations based on problematic student behaviours. Ultimately, we are unable to differentiate these processes, but future work could identify what mechanisms drive the shift in variance, particularly as it relates to the strongest correlates we found, perceived school and parent goal structure.

More fundamentally, the result that older students display higher genetic variance indicates that behaviour genetic statistics like heritability are not static. Heritability may rise and fall rather quickly across development, particularly during periods of social and environmental change. This provides another clear example that both environmental and genetic influences play a role in one's adaptive development. Future longitudinal data could identify whether the observed age trends reflect novel genetic variance or the strengthening of existing variance. This information could shed additional light on the mechanisms driving declining academic motivation with age.

Unexpectedly, we observed that genetic variance sharply decreased as students approached graduation, and shared environmental variance increased. If the mechanisms suggested earlier, personality factors becoming relevant or gene–environment correlation guiding growth, were relatively enduring aspects of development, then we should expect heritability to remain high, even in the face of major transitions. As an example, genetic influences on cognitive ability increase over a similar timespan but remain at adolescent levels across adulthood even across substantial transitions in education. One potential explanation is that motivational processes might be more sensitive to the economic realities of higher education in the USA, which has the highest average tuition cost in the world (OECD, 2017, pp. 220). Some students likely had to face realities of not being able to afford college and instead looked for work. Put differently, family-level social capital, either in terms of financial resources or experience with the educational system, might have exerted more influence on student mastery goal orientation as high stakes decisions were being made. These novel findings should be replicated before drawing firm conclusions, and future studies could test the mediation effect of socioeconomic status on the genetic and environmental pathway of mastery goal orientation.

DOI: 10.1002/per

We can also draw some tentative implications for the identified mean-level trend. For example, it may be the case that students are primarily exposed to positive and supportive parental and school mastery goal structures. As students mature and rely on their openness to experience to inform their mastery goal orientation, there is likely to be a greater representation of low openness students compared with parents who believe learning for learning's sake is unimportant. Such a shift could lead to the observed mean-level decline. Similarly, novel environmental pressures, such as an increasing importance placed on peers and social relationships, might alter the factors that students draw upon to inform their mastery goal orientation. Peer pressure may lead some students to rely less on values transmitted from school or parents. Our results would be consistent with this process, and then students may draw on their genetically influenced characteristics to fill the void.

A major applied impetus for examining age trends in mean levels of achievement goal orientations is to identify when in development interventions should be targeted such that the intervention only needs to *maintain* motivation rather than increase motivation. Our results are consistent with previous work identifying the downward shift occurring particularly quickly between ages 10 to 14 years (e.g. Bong, 2001). The current results imply that interventions targeting this age range are also targeting a time when the developmental influences on achievement goal orientations are shifting from family-level factors to genetically influenced characteristics. Of course, behaviour genetic studies only assess naturally occurring variation in the population of study, not what sorts of interventions are possible. That being said, it may be useful for applied researchers to consider this shift when crafting interventions.

Impact of perceived parent and school goal structures

Based on previous work, we anticipated that student goal orientations would be moderately correlated with the perceived goal structure of parents and schools (Meece et al., 2006). Intuitively, parents and schools may play a causal socialization role by instilling certain values in young students. Although we consistently found moderate correlations, the behaviour genetic analyses seem to imply a somewhat different causal connection. Turkheimer, Pettersson, and Horn (2014) proposed a phenotypic null hypothesis for personality. To the extent that personality plays a causal role in the development of some outcome, we should expect that the magnitude of genetic and environmental associations would mirror the genetic and environmental influences on personality. If personality matters, rather than abstract and hidden sources genetic and environmental variance, then the genetic and environmental influences on personality should transfer over to the outcome (Briley, Livengood, & Derringer, 2018).

We consistently found substantial shared environmental variance for the parent and school measures of achievement goal orientations. Yet we found essentially no shared environmental variance for the student's achievement goal orientations. If schools or parents were active socializers, then it would be expected that some shared environmental variance would be found for the student's achievement goal orientations. Our results are inconsistent with this expectation. Rather, the results are more consistent with the student's achievement goal orientations shaping the parent or school. For example, the genetic influences that we identified for the school and parent goal structures may have emerged because of the expression of the student's genetically influenced characteristics. Put differently, the association between student perception and student achievement goal orientations may have been driven more by the student's characteristics guiding perception, rather than the environment shaping the student's characteristics.

Several caveats are important. First, parents and schools may not influence goal orientations in a way that makes siblings more similar to one another. Parent and school goal structures could primarily exert their influence through a nonshared pathway. In fact, we consistently found nonshared environmental associations. This result implies that the student who perceives that his or her parents or school is more focused on mastery goal orientation also tends to express a stronger mastery goal orientation. More specifically, our results are consistent with making this comparison between identical twins raised in the same home, a more stringent test than simply comparing across students. Parents and teachers may be able to tailor their socialization practices based on the unique characteristics of each child.

Second, we measured student perceptions of parent and school goal structure, rather than direct measures of the environment. It may be the case that parents or teachers might report different goal structures than what are perceived by the student. Future studies should include direct measures of parental and school goal structures. Genetically influenced characteristics of the student may flavour perception, which could account for the genetic influences on parent and school goal structures as well as the genetic association with student mastery goal orientation.

Finally, we did observe some shared environmental influences on mastery goal orientation at young and older ages. Unfortunately, the perceived parent and school goal structure measures were only available for a subset of participants, making an analysis of these specific age ranges underpowered. Future work could identify specific mechanisms of the nonshared environmental associations, compare student perception with measures taken from teachers or parents, and perhaps target participant recruitment to test whether shared environmental variance at early ages is associated with environmental goal structures.

Strengths and limitations

The current study draws on several strengths. We used a large, diverse, age-heterogeneous sample to test the novel question of whether the magnitude of genetic and environmental influences on achievement goal orientations shifts alongside mean levels. Despite these strengths, several limitations are important to consider.

First, the current study was cross-sectional and not longitudinal. This design feature prevents us from making

DOI: 10.1002/per

inferences regarding longitudinal change in achievement goal orientation. However, previous cross-sectional and longitudinal studies evaluating age trends in achievement goal orientations have been remarkably consistent. Future longitudinal studies should test the identified trends.

Second, we identified somewhat unexpected age trends in the genetic and environmental influences on mastery goal orientation. We did not have access to another similar dataset to replicate this trend. Care should be taken in interpreting these results until replicated with independent data.

Third, although we had a substantial sample size for the primary study variables, sample size was limited for several of the contextual variables. Again, care should be taken in interpreting the point estimates related to parent and school achievement goal orientations and peer relationships as these were estimated with less precision. Larger sample sizes would also be required to test whether the genetic and environmental associations between achievement goal orientations and the contextual variables shift with age.

Fourth, the included measures differed in length and reliability. Lower reliability may have obscured age trends and associations. In particular, performance avoidance orientation had relatively low reliability. Future work using more psychometrically sound assessments may identify age trends or associations not observed in this study.

Finally, we encountered estimation difficulties in our bivariate behaviour genetic models. We solved this issue by fixing the shared environmental covariance between the achievement goal orientations and the contextual and psychological variables to zero. This decision was justified by the trivial amount of shared environmental variance in the achievement goal orientations. However, future work with larger sample sizes could investigate other behaviour genetic models to gain a more complete picture of the associations.

CONCLUSIONS

Our goal was to shed light on the potential mechanisms that drive the downward trajectory of academic motivation across the school years. We used behaviour genetic methodology to identify whether the mean-level decline in achievement goal orientations was accompanied by shifts in the genetic and environmental influences on achievement goal orientations. We identified such a shift for mastery goal orientation; students increasingly form their mastery goal orientation on the basis of genetically influenced characteristics from elementary school until high school. This result points towards student characteristics perhaps playing an important role in understanding the decline in academic motivation. We additionally found that the association between mastery goal orientation and openness to experience increased alongside this trend. Student motivation fluctuates across child development in response to many inputs, including genetic and environmental influences. More work is needed to understand how each of these components is interconnected across time.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Zero-order correlation
Figure S1. Distribution of age on each variable with full sample, MZ pairs and DZ pairs. Cog.ab = cognitive ability.
Figure S2. LOSEM result showing the mean-level age trends for the perceived school goal structures, perceived parental goals, peer relationship, cognitive ability, conscientiousness, and openness.
Figure S3. LOSEM result showing the between-person variance age trends for the perceived school goal structures, perceived parental goals, peer relationship, cognitive ability, conscientiousness, and openness.
Figure S4. Age-trends in proportion of variance composite to genetic and environmental components for mastery, performance approach, and performance avoidance goal orientations using a (A) nonparametric and (B) parametric approach.

REFERENCES

Anderman, E. M., & Midgley, C. (1997). Changes in achievement goal orientations, perceived academic competence, and grades across the transition to middle-level schools. *Contemporary Educational Psychology*, *22*, 269–298 https://doi.org/10.1006/ceps.1996.0926.

Anderman, L. H., & Anderman, E. M. (1999). Social predictors of changes in students' achievement goal orientations. *Contemporary Educational Psychology*, *24*, 21–37 https://doi.org/10.1006/ceps.1998.0978.

Anderson, A., Hamilton, R. J., & Hattie, J. (2004). Classroom climate and motivated behaviour in secondary schools. *Learning Environments Research*, *7*, 211–225 https://doi.org/10.1007/s10984-004-3292-9.

Ayoub, M., Briley, D. A., Grotzinger, A., Patterson, M. W., Engelhardt, L. E., Tackett, J. L., Harden, K. P., et al. (2018). Genetic and environmental associations between child personality and parenting. *Social Psychological and Personality Science*, 6–8 https://doi.org/10.1177/1948550618784890.

Bergen, S. E., Gardner, C. O., & Kendler, K. S. (2007). Age-related changes in heritability of behavioral phenotypes over adolescence and young adulthood: A meta-analysis. *Twin Research and Human Genetics*, *10*, 423–433 https://doi.org/10.1375/twin.10.3.423.

Bleidorn, W., Kandler, C., & Caspi, A. (2014). The behavioral genetics of personality development in adulthood-classic, contemporary, and future trends. *European Journal of Personality*, *28*, 244–255 https://doi.org/10.1002/per.1957.

Bong, M. (2001). Between- and within-domain relations of academic motivation among middle and high school students: Self-efficacy, task-value, and achievement goals. *Journal of Educational Psychology*, *93*, 23–34 https://doi.org/10.1037/0022-0663.93.1.23.

Briley, D. A., Harden, K. P., Bates, T. C., & Tucker-Drob, E. M. (2015). Nonparametric estimates of gene × environment interaction using local structural equation modeling. *Behavior Genetics*, *45*, 581–596 https://doi.org/10.1007/s10519-015-9732-8.

Briley, D. A., Livengood, J., & Derringer, J. (2018). Behaviour genetic frameworks of causal reasoning for personality psychology. *European Journal of Personality*, *32*, 202–220 https://doi.org/10.1002/per.2153.

Briley, D. A., & Tucker-Drob, E. M. (2013). Explaining the increasing heritability of cognitive ability across development: A meta-

DOI: 10.1002/per

analysis of longitudinal twin and adoption studies. *Psychological Science*, *24*, 1704–1713 https://doi.org/10.1177/0956797613478618.

Briley, D. A., & Tucker-Drob, E. M. (2014). Genetic and environmental continuity in personality development: A meta-analysis. *Psychological Bulletin*, *140*, 1303–1331 https://doi.org/10.1037/a0037091.

Bronfenbrenner, U., & Ceci, S. J. (1994). Nature–nurture reconceptualized in developmental perspective: A bioecological model. *Psychological Review*, *101*, 568–586 https://doi.org/10.1037/0033-295X.101.4.568.

Button, S. B., Mathieu, J. E., & Zajac, D. M. (1996). Goal orientation in organizational research: A conceptual and empirical foundation. *Organizational Behavior and Human Decision Processes*, *67*, 26–48 https://doi.org/10.1006/obhd.1996.0063.

Chouinard, R., & Roy, N. (2008). Changes in high-school students' competence beliefs, utility value and achievement goals in mathematics. *British Journal of Educational Psychology*, *78*, 31–50 https://doi.org/10.1348/000709907X197993.

Church, M. A., Elliot, A. J., & Gable, S. L. (2001). Perceptions of classroom environment, achievement goals, and achievement outcomes. *Journal of Educational Psychology*, *93*, 43–54 https://doi.org/10.1037/0022-0663.93.1.43.

Cleveland, W. S., & Devlin, S. J. (1988). Locally weighted regression: An approach to regression analysis by local fitting. *Journal of the American Statistical Association*, *83*, 596–610 https://doi.org/10.1080/01621459.1988.10478639.

Deary, I. J., Whalley, L. J., Lemmon, H., Crawford, J. R., & Starr, J. M. (2000). The stability of individual differences in mental ability from childhood to old age: Follow-up of the 1932 Scottish mental survey. *Intelligence*, *28*, 49–55 https://doi.org/10.1016/S0160-2896(99)00031-8.

Deemer, S. A. (2004). Classroom goal orientation in high school classrooms: Revealing links between teacher beliefs and classroom environments. *Educational Research*, *46*, 73–90 https://doi.org/10.1080/0013188042000178836.

Dickens, W. T., & Flynn, J. R. (2001). Heritability estimates versus large environmental effects: The IQ paradox resolved. *Psychological Review*, *108*, 346–369 https://doi.org/10.1037/0033-295X.108.2.346.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist*, *41*, 1040–1048 https://doi.org/10.1037/0003-066X.41.10.1040.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, *53*, 109–132 https://doi.org/10.1146/annurev.psych.53.100901.135153.

Eison, J. A. (1981). A new instrument for assessing students' orientations towards grades and learning. *Psychological Reports*, *48*, 919–924 https://doi.org/10.2466/pr0.1981.48.3.919.

Elliot, A. J., & Harackiewicz, J. M. (1996). Approach and avoidance achievement goals and intrinsic motivation: A mediational analysis. *Journal of Personality and Social Psychology*, *70*, 461–475 https://doi.org/10.1037/0022-3514.70.3.461.

Elliot, A. J., & McGregor, H. A. (2001). A 2 × 2 achievement goal framework. *Journal of Personality and Social Psychology*, *80*, 501–519 https://doi.org/10.1037/0022-3514.80.3.501.

Friedel, J. M., Cortina, K. S., Turner, J. C., & Midgley, C. (2007). Achievement goals, efficacy beliefs and coping strategies in mathematics: The roles of perceived parent and teacher goal emphases. *Contemporary Educational Psychology*, *32*, 434–458 https://doi.org/10.1016/j.cedpsych.2006.10.009.

Fryer, J. W., & Elliot, A. J. (2007). Stability and change in achievement goals. *Journal of Educational Psychology*, *99*, 700–714 https://doi.org/10.1037/0022-0663.99.4.700.

Gonida, E. N., Voulala, K., & Kiosseoglou, G. (2009). Students' achievement goal orientations and their behavioral and emotional engagement: Co-examining the role of perceived school goal structures and parent goals during adolescence. *Learning and Individual Differences*, *19*, 53–60 https://doi.org/10.1016/j.lindif.2008.04.002.

Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic motivation from childhood through late adolescence: A longitudinal study. *Journal of Educational Psychology*, *93*, 3–13 https://doi.org/10.1037/0022-0663.93.1.3.

Hallquist, M. N., & Wiley, J. F. (2018). MplusAutomation: An R package for facilitating large-scale latent variable analyses in Mplus. *Structural Equation Modeling*, *25*, 621–638 https://doi.org/10.1080/10705511.2017.1402334.

Harackiewicz, J. M., Barron, K. E., Tauer, J. M., & Elliot, A. J. (2002). Predicting success in college: A longitudinal study of achievement goals and ability measures as predictors of interest and performance from freshman year through graduation. *Journal of Educational Psychology*, *94*, 562–575 https://doi.org/10.1037/0022-0663.94.3.562.

Harden, K. P., Tucker-Drob, E. M., & Tackett, J. L. (2013). The Texas Twin Project. *Twin Research and Human Genetics*, *16*, 385–390 https://doi.org/10.1017/thg.2012.97.

Heath, A. C., Nyholt, D. R., Neuman, R., Madden, P. A. F., Bucholz, K. K., Todd, R. D., … Martin, N. G. (2003). Zygosity diagnosis in the absence of genotypic data: An approach using latent class analysis. *Twin Research*, *6*, 22–26 https://doi.org/10.1375/136905203762687861.

Hildebrandt, A., Lüdtke, O., Robitzsch, A., Sommer, C., & Wilhelm, O. (2016). Exploring factor model parameters across continuous variables with local structural equation models. *Multivariate Behavioral Research*, *51*, 257–258 https://doi.org/10.1080/00273171.2016.1142856.

Hsieh, P. H., Sullivan, J. R., & Guerra, N. S. (2007). A closer look at college students: Self-efficacy and goal orientation. *Journal of Advanced Academics*, *18*, 454–476 https://doi.org/10.4219/jaa-2007-500.

Huang, C. (2012). Discriminant and criterion-related validity of achievement goals in predicting academic achievement: A meta-analysis. *Journal of Educational Psychology*, *104*, 48–73 https://doi.org/10.1037/a0026223.

Hudson, W. (1990). A short-form scale to measure peer relations dysfunction. *Journal of Social Service Research*, *13*, 57–69 https://doi.org/10.1300/J079v13n04_04.

John, O., Naumann, L., & Soto, C. (2008). Paradigm shift to the integrative Big Five Trait taxonomy. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality: Theory and research* (pp. 114–158). New York, NY: Guilford Press.

Johnson, W. (2007). Genetic and environmental influences on behavior: Capturing all the interplay. *Psychological Review*, *114*, 423–440 https://doi.org/10.1037/0033-295X.114.2.423.

Kandler, C., & Papendick, M. (2017). Behavior genetics and personality development: A methodological and meta-analytic review. In J. Specht (Ed.), *Personality development across the lifespan* (pp. 473–495). San Diego, CA: Elsevier Inc.

Kaplan, A., & Midgley, C. (1999). The relationship between perceptions of the classroom goal structure and early adolescents' affect in school: The mediating role of coping strategies. *Learning and Individual Differences*, *11*, 187–212 https://doi.org/10.1016/S1041-6080(00)80005-9.

Kendler, K. S., & Baker, J. H. (2007, May). Genetic influences on measures of the environment: A systematic review. *Psychological Medicine*, *37*, 615–626 https://doi.org/10.1017/S0033291706009524.

Komarraju, M., & Karau, S. J. (2005). The relationship between the Big Five personality traits and academic motivation. *Personality and Individual Differences*, *39*, 557–567 https://doi.org/10.1016/j.paid.2005.02.013.

Komarraju, M., Karau, S. J., & Schmeck, R. R. (2009). Role of the Big Five personality traits in predicting college students' academic motivation and achievement. *Learning and Individual Differences*, *19*, 47–52 https://doi.org/10.1016/j.lindif.2008.07.001.

Kovas, Y., Garon-Carrier, G., Boivin, M., Petrill, S. A., Plomin, R., Malykh, S. B., Spinath, F., … Vitaro, F. (2015). Why children differ in motivation to learn: Insights from over 13,000 twins from 6 countries. *Personality and Individual Differences*, *80*, 51–63 https://doi.org/10.1016/j.paid.2015.02.006.

Luo, Y. L. L., Kovas, Y., Haworth, C. M. A., & Plomin, R. (2011). The etiology of mathematical self-evaluation and mathematics achievement: Understanding the relationship using a cross-lagged twin study from ages 9 to 12. *Learning and Individual Differences*, *21*, 710–718 https://doi.org/10.1016/j.lindif.2011.09.001.

Malanchini, M., Wang, Z., Voronin, I., Schenker, V. J., Plomin, R., Petrill, S. A., & Kovas, Y. (2017). Reading self-perceived ability, enjoyment and achievement: A genetically informative study of their reciprocal links over time. *Developmental Psychology*, *53*, 698–712 https://doi.org/10.1037/dev0000209.

Manuck, S. B., & McCaffery, J. M. (2014). Gene–environment interaction. *Annual Review of Psychology*, *65*, 41–70 https://doi.org/10.1146/annurev-psych-010213-115100.

McGue, M., & Bouchard, T. J. (1984). Adjustment of twin data for the effects of age and sex. *Behavior Genetics*, *14*, 325–343 https://doi.org/10.1007/BF01080045.

McNeish, D., Stapleton, L. M., & Silverman, R. D. (2017). On the unnecessary ubiquity of hierarchical linear modeling. *Psychological Methods*, *22*, 114–140 https://doi.org/10.1037/met0000078.

Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation, and academic achievement. *Annual Review of Psychology*, *57*, 487–503 https://doi.org/10.1146/annurev.psych.56.091103.070258.

Meece, J. L., & Miller, S. D. (2001). A longitudinal analysis of elementary school students' achievement goals in literacy activities. *Contemporary Educational Psychology*, *26*, 454–480 https://doi.org/10.1006/ceps.2000.1071.

Midgley, C., Kaplan, A., & Middleton, M. (2001). Performance-approach goals: Good for what, for whom, under what circumstances, and at what cost? *Journal of Educational Psychology*, *93*, 77–86 https://doi.org/10.1037/0022-0663.93.1.77.

Midgley, C., Maehr, M. L., Hicks, L., Roeser, R., Urdan, T., Anderman, E. M., … Middleton, M. J. (2000). Affirming entrepreneurial education: Learning, employability and personal development. In *Manual for the patterns of adaptive learning scales*. University of Michigan. https://doi.org/10.1108/00197851211231450.

Murayama, K., & Elliot, A. J. (2009). The joint influence of personal achievement goals and classroom goal structures on achievement-relevant outcomes. *Journal of Educational Psychology*, *101*, 432–447 https://doi.org/10.1037/a0014221.

Muthén, L. K., & Muthén, B. O. (2017). A user' guide to clozapine. In *Mplus user's guide* (Eighth ed., pp. 407–408), *123*. Los Angeles, CA: Muthén & Muthén.

Neale, M. C., & Cardon, L. R. (1992). *Methodology for genetic studies of twins and families*. Netherlands: Springer.

Nelson, R. M., & Debacker, T. K. (2008). Achievement motivation in adolescents: The role of peer climate and best friends. *Journal of Experimental Education*, *76*, 170–189 https://doi.org/10.3200/JEXE.76.2.170-190.

Obach, M. S. (2003). A longitudinal-sequential study of perceived academic competence and motivational beliefs for learning among children in middle school. *Educational Psychology*, *23*, 323–338 https://doi.org/10.1080/0144341032000060156.

O'Connor, M. C., & Paunonen, S. V. (2007). Big Five personality predictors of post-secondary academic performance. *Personality and Individual Differences*, *43*, 971–990 https://doi.org/10.1016/j.paid.2007.03.017.

OECD (2017). *Education at a glance 2017: OECD indicators*. Paris: OECD Publishing.

Pajares, F., & Cheong, Y. F. (2003). Achievement goal orientations in writing: A developmental perspective. *International Journal of Educational Research*, *39*, 437–455 https://doi.org/10.1016/j.ijer.2004.06.008.

Payne, S. C., Youngcourt, S. S., & Beaubien, J. M. (2007). A meta-analytic examination of the goal orientation nomological net. *Journal of Applied Psychology*, *92*, 128–150 https://doi.org/10.1037/0021-9010.92.1.128.

Pintrich, P. R. (2000). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology*, *92*, 544–555 https://doi.org/10.1037/0022-0663.92.3.544.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*, 33–40 https://doi.org/10.1016/0960-8524(94)90166-X.

Plomin, R., DeFries, J. C., & Loehlin, J. C. (1977). Genotype–environment interaction and correlation in the analysis of human behavior. *Psychological Bulletin*, *84*, 309–322 https://doi.org/10.1037/0033-2909.84.2.309.

Poropat, A. E. (2009). A meta-analysis of the five-factor model of personality and academic performance. *Psychological Bulletin*, *135*, 322–338 https://doi.org/10.1037/a0014996.

Purcell, S. (2002). Variance components models for gene–environment interaction in twin analysis. *Twin Research*, *5*, 554–571 https://doi.org/10.1375/136905202762342026.

Rieger, S., Göllner, R., Spengler, M., Trautwein, U., Nagengast, B., & Roberts, B. W. (2017). Social cognitive constructs are just as stable as the Big Five between grades 5 and 8. *AERA Open*, *3*, 1–9 https://doi.org/1.1177/2332858417717691.

Roberts, B. W., Walton, K. E., & Viechtbauer, W. (2006). Patterns of mean-level change in personality traits across the life course: A meta-analysis of longitudinal studies. *Psychological Bulletin*, *132*, 1–25 https://doi.org/10.1037/0033-2909.132.1.1.

Roseth, C. J., Johnson, D. W., & Johnson, R. T. (2008). Promoting early adolescents' achievement and peer relationships: The effects of cooperative, competitive, and individualistic goal structures. *Psychological Bulletin*, *134*, 223–246 https://doi.org/10.1037/0033-2909.134.2.223.

Rumberger, R. W. (1987). High school dropouts: A review of issues and evidence. *Review of Educational Research*, *57*, 101–121 https://doi.org/10.3102/00346543057002101.

Scarr, S., & McCartney, K. (1983). How people make their own environments: A theory of genotype → environment effects. *Child Development*, *54*, 424–435 https://doi.org/10.2307/1129703.

Schiefele, U., & Schaffner, E. (2015). Teacher interests, mastery goals, and self-efficacy as predictors of instructional practices and student motivation. *Contemporary Educational Psychology*, *42*, 159–171 https://doi.org/10.1016/j.cedpsych.2015.06.005.

Schwinger, M., Steinmayr, R., & Spinath, B. (2016). Achievement goal profiles in elementary school: Antecedents, consequences, and longitudinal trajectories. *Contemporary Educational Psychology*, *46*, 164–179 https://doi.org/10.1016/j.cedpsych.2016.05.006.

Senko, C., & Harackiewicz, J. M. (2005). Regulation of achievement goals: The role of competence feedback. *Journal of Educational Psychology*, *97*, 320–336 https://doi.org/10.1037/0022-0663.97.3.320.

Senko, C., Hulleman, C. S., & Harackiewicz, J. M. (2011). Achievement goal theory at the crossroads: Old controversies, current challenges, and new directions. *Educational Psychologist*, *46*, 26–47 https://doi.org/10.1080/00461520.2011.538646.

Shim, S. S., Ryan, A. M., & Anderson, C. J. (2008). Achievement goals and achievement during early adolescence: Examining time-varying predictor and outcome variables in growth-curve analysis. *Journal of Educational Psychology*, *100*(3), 655.

Soto, C. J., & Tackett, J. L. (2015). Personality traits in childhood and adolescence: Structure, development, and outcomes. *Current Directions in Psychological Science*, *24*, 358–362 https://doi.org/10.1177/0963721415589345.

Strenze, T. (2007). Intelligence and socioeconomic success: A meta-analytic review of longitudinal research. *Intelligence*, *35*, 401–426 https://doi.org/10.1016/j.intell.2006.09.004.

Tucker-Drob, E. M. (2009). Differentiation of cognitive abilities across the life span. *Developmental Psychology*, *45*, 1097–1118 https://doi.org/10.1037/a0015864.

Tucker-Drob, E. M., & Briley, D. A. (2014). Continuity of genetic and environmental influences on cognition across the life span: A meta-analysis of longitudinal twin and adoption studies. *Psychological Bulletin*, *140*, 949–979 https://doi.org/10.1037/a0035893.

Tucker-Drob, E. M., & Briley, D. A. (2019). Theoretical concepts in the genetics of personality development. In D. McAdams, R. L. Shiner, & J. L. Tackett (Eds.), *The handbook of personality development* (pp. 40–58). New York, NY: Guilford Press.

Tucker-Drob, E. M., Briley, D. A., Engelhardt, L. E., Mann, F. D., & Harden, K. P. (2016). Genetically-mediated associations between measures of childhood character and academic achievement. *Journal of Personality and Social Psychology*, *111*, 790–815 https://doi.org/10.1037/pspp0000098.

Tucker-Drob, E. M., Briley, D. A., & Harden, K. P. (2013). Genetic and environmental influences on cognition across development and context. *Current Directions in Psychological Science*, *22*, 349–355 https://doi.org/10.1177/0963721413485087.

Tucker-Drob, E. M., & Harden, K. P. (2017). A behavioral genetic perspective on noncognitive factors and academic achievement. In S. Bouregy, E. Grigorenko, S. Latham, & M. Tan (Eds.), *Current perspective in psychology: Genetics, ethics, and education*. Cambridge: Cambridge University Press.

Tully, L. A., Moffitt, T. E., Caspi, A., Taylor, A., Kiernan, H., & Andreou, P. (2004). What effect does classroom separation have on twins' behavior, progress at school, and reading abilities. *Twin Research and Human Genetics*, *7*, 115–124 https://doi.org/10.1375/twin.7.2.115.

Turkheimer, E., Pettersson, E., & Horn, E. E. (2014). A phenotypic null hypothesis for the genetics of personality. *Annual Review of Psychology*, *65*, 515–540 https://doi.org/10.1146/annurev-psych-113011-143752.

Urdan, T. C. (1997). Examining the relations among early adolescent students' goals and friends' orientation toward effort and achievement in school. *Contemporary Educational Psychology*, *22*, 165–191 https://doi.org/10.1006/ceps.1997.0930.

Van Yperen, N. W., Blaga, M., & Postmes, T. (2014). A meta-analysis of self-reported achievement goals and nonself-report performance across three achievement domains (work, sports, and education). *PLoS ONE*, *9*, e93594 https://doi.org/10.1371/journal.pone.0093594.

Wechsler, D. (2013). WASI-II: Wechsler Abbreviated Scale of Intelligence—second edition. *Journal of Psychoeducational Assessment*, *31*, 337–341 https://doi.org/citeulike-article-id:6135820.

Wigfield, A., Eccles, J. S., Schiefele, U., Roeser, R. W., & Davis-Kean, P. (2007). Development of achievement motivation. In *Handbook of child psychology*. Hoboken, NJ, USA: John Wiley & Sons, Inc.

Wolters, C. A. (2004). Advancing achievement goal theory: Using goal structures and goal orientations to predict students' motivation, cognition, and achievement. *Journal of Educational Psychology*, *96*(2), 236.

DOI: 10.1002/per