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Received: 2 December 2020 | Revised: 18 November 2021 | Accepted: 9 April 2022

DOI: 10.1111/jopy.12723

ORIGINAL ARTICLE

WILEY

Genetics, parenting, and family functioning—What drives the development of self-control from adolescence to adulthood?

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Funding information
Deutsche Forschungsgemeinschaft

Abstract

Objective: Self-control is a meaningful predictor of crucial life outcomes. Knowingly, genes contribute substantially to differences in self-control, but behavioral genetic findings are often misinterpreted regarding environmental influences. Therefore, we reinvestigate the heritability of self-control as well as potential environmental influences, namely parenting and a chaotic home environment.

Method: We used cross-sectional and longitudinal data from the German twin family study TwinLife ($N = 3354$ individuals), structured in a multicohort design in which 13-, 19-, and 25-year-old twins rated their self-control, parents' behavior, and home environment.

Results: Results showed increasing mean levels and 1-year stabilities for self-control accompanied by substantial genetic influences, increasing particularly from ages 19 to 25 (53% to 76%). While chaotic home environments and negative parenting were phenotypically associated with lower self-control, twin difference models revealed that differences in these individually perceived "environments" directly predicted self-control differences ($\beta = -0.16$ to -0.28) within families when controlling for genetic and environmental similarities.

Conclusions: In addition to the genetic anchoring of self-control, results indicate that environmental factors such as negative family environments are meaningful and depend on individual perceptions within families. Interventions for enhancing self-control should, therefore, rely on individual perspectives rather than objective characteristics of home environments.

KEYWORDS

CHAOS, genetics, parenting style, personality, self-control

1 | INTRODUCTION

There are substantial individual differences in self-control: one individual may find it easy to resist temptation and pursue long-term goals, whereas another person may need to put a lot of effort into controlling their behavior and may frequently fail. Self-control has been identified as a meaningful predictor of crucial life outcomes, such as physical health, financial security, educational and occupational success, and integrity (Mischel et al., 2011;

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Moffitt et al., 2011). It, therefore, seems to be of central importance to understand *how* self-control differences between individuals develop. To what extent can we explain these differences by referring to our individual genetic endowments, and how much and how exactly do environmental influences, our experiences, and what we have learnt contribute to our self-control skills? Do these relative influences on self-control change across development? Furthermore, at some point in life, does self-control stabilize?

In the current study, we combined a behavior genetic approach to examine the relative contributions of genetic and environmental factors on self-control with an additional investigation of the role of certain environmental factors, thereby aiming to bring together theoretical ideas and empirical findings from individual differences and social psychology disciplines. Knowledge of the mechanisms that underlie self-control will aid the understanding of whether and how an environmental influence (e.g., parenting style) has a direct environmental effect on self-control or whether its effect appears in the form of a genetic influence through its interplay with genetic propensities.

1.1 | Theories on the development of self-control

In the present study, we operationalized self-control as a composite that combines self-control and consistency of interest, which is one subscale of grit. Self-control describes the propensity to adapt one's inner responses and to inhibit undesired behavioral tendencies (Tangney et al., 2004). Grit refers to perseverance and passion in the pursuit of long-term goals, and consistency of interest therein represents the part of grit that is related to the maintenance of goals and interests over time (Duckworth et al., 2007). Since different studies revealed a substantial overlap of $r \geq 0.58$ between self-control and grit (Muenks et al., 2017; Saunders et al., 2018; Werner et al., 2019) and another study showed that grit can be considered an indicator of a higher order self-control term (Vazsonyi et al., 2019), we use the term self-control to describe our composite of self-control and grit. We further refer to the definition of self-control by Tangney et al. (2004) as our working definition.

The development of self-control begins (at least) early in life (Kochanska et al., 2000; McClelland & Cameron, 2012; Moffitt et al., 2011). Evidence suggests that inhibitory competencies such as delay of gratification—the ability to resist an immediate reward to obtain a later, more valuable reward (Mischel et al., 2011)—increase, whereas impulsive (uncontrolled) behavior declines from childhood to age 30 (Steinberg et al., 2008, 2009). In the present work, we will discuss two main perspectives on the origins of self-control: the personality perspective and the cognitive perspective.

Similar to self-control, the development of personality is not complete in childhood but rather continues through adolescence and adulthood (Caspi & Roberts, 2001). Through the lens of personality psychology, self-control processes are stable tendencies reflected in personality traits, especially conscientiousness (Hoyle, 2006; Roberts et al., 2012). Individuals high on trait conscientiousness are characterized by, for example, tidiness, achievement striving, and self-discipline (Costa et al., 1991). Consistent with this definition, there is evidence for substantial correlations between conscientiousness and self-control (e.g., Tangney et al., 2004: $r = 0.47$ to 0.49, controlled for social desirability), indicating that people high on conscientiousness tend to show more self-control. Regarding the development over the life course, personality traits have shown considerable cross-temporal and situational stability. McCrae and Costa Jr. (1994) stated that personality traits are essentially fixed in adulthood and that there are only a few and subtle changes after age 30. In contrast to this view, Roberts and DelVecchio (2000) showed that overall trait consistency increases with age, but it does not peak until after age 50, and there is no specific point in life when personality traits stop changing.

By contrast, the cognitive perspective views self-control in the light of information processing. From this perspective, self-control processes are conscious, effortful, and characterized by the monitoring, maintaining, and modifying of behaviors to achieve a goal (Hoyle, 2006). Research has revealed that executive functions are involved in top-down processes of self-control and thereby contribute to the successful control of behavior (Hofmann et al., 2012; Nigg, 2017). The development of executive functions goes along with brain development, mainly of the prefrontal cortex (Diamond, 2002, 2013).

1.1.1 | Behavior genetic methods

The present study examines the etiology of self-control in adolescence and young adulthood by estimating the relative contributions of genetic and specific environmental influences on the development of self-control and thereby aims to uncover underlying mechanisms in the etiology of self-control differences. To this end, we used data from the *TwinLife* study, a large, representative German panel for studying monozygotic (MZ) and same-sex dizygotic twins (DZ) as well as their families (Hahn et al., 2016).[1] One major purpose of the present contribution is to make behavior genetic methods more accessible to researchers

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interested in self-control who are otherwise unfamiliar with these methods. Therefore, in the following, we introduce behavior genetic methods and previous research on self-control that made use of such methods.

In behavior genetic studies, groups with different degrees of known genetic (or environmental) relatedness (here monozygotic and dizygotic twins) are studied to uncover sources of variation in phenotypes. The typical question is: To what extent can the phenotypic variation be explained by genetic and environmental influences? The extent to which genetic differences are associated with observable phenotypic differences is called heritability. To address different mechanisms that determine how genes exert their effects on behavior, genetic influences can be further decomposed into additive genetic and nonadditive components of genetic variance (Knopik et al., 2017). Additive genetic variance (A) refers to the independent effects of alleles[2] or loci that add up, in contrast to nonadditive genetic variance in which the effects of alleles or loci interact. There are two types of nonadditive genetic variance: Dominance (D) occurs when the effect of one allele depends on that of another allele at the same locus. Epistasis refers to nonadditive effects between alleles at different loci. Thus, compared with less genetically related individuals (e.g., dizygotic twins), genetically identical individuals (monozygotic twins) become linearly more similar on a trait when additive genetic variance influences the trait, and they become disproportionately more similar when the genetic effects of dominance or epistasis occur (Mõttus et al., 2019).

Although the above distinction between different genetic effects is still simplified,[3] many studies have considered genetic influences only in the sense of additive influences. Therefore, heritability in a narrow sense is defined as the ratio of additive genetic variance to total phenotypic variance. In a broad sense, it refers to the ratio of total genetic variance to total phenotypic variance, comprising also nonadditive effects. Nevertheless, the distinction between additive and nonadditive genetic variance is important because family histories of traits depend on whether these traits are influenced by narrow or broad-sense heritability (Hatemi et al., 2010). Additive and nonadditive effects, therefore, indicate how much similarity we can expect in the expressions of traits from one generation to the next.

The diversity of environmental influences can be categorized into shared/common (C) and nonshared/unique environmental influences (E) (Knopik et al., 2017). Shared environmental influences refer to the extent to which the (same) rearing environment leads to similarities among phenotypes, regardless of genetic relatedness. Nonshared environmental influences (e.g., unique life experiences) index effects that cause dissimilarity in individuals from the same rearing environment. However, these definitions are also simplified, and the distinction between shared and nonshared environments is difficult insofar as it is merely based on differential effects on the phenotype.

The relative impact of genetic and environmental influences is typically analyzed in groups of participants with known genetic relatedness, such as monozygotic (or identical) and dizygotic (or fraternal) twins. The extent of the similarity between monozygotic and dizygotic twins indicates how much of the variance in a trait can be explained by genes and the different environmental influences. If genes are relevant for a trait, genetically identical twins must be more similar than fraternal twins, who on average share 50% of their additive and only 25% of their nonadditive genetic dominance effects.[4] If monozygotic twins are more than twice as similar as dizygotic twins are, genetic dominance effects are assumed. Furthermore, less than perfect monozygotic twin correlations are attributed to nonshared environmental influences, and high similarity in both twin pairs indicates shared environmental influences on a trait. These assumptions are based on the equal environment assumption of the twin method, which states that shared environmental influences contribute equally to the similarity of monozygotic and dizygotic twins who are reared together (Hahn et al., 2013; Knopik et al., 2017).

1.1.2 | The relative contributions of genetic and environmental influences on self-control

A recent meta-analysis compared the relative additive genetic and environmental influences on cognitive ability and personality over the life span (Briley & Tucker-Drob, 2017). With respect to cognitive ability (e.g., general intelligence, reasoning, and memory), the findings revealed greatly increasing genetic influences on cognitive abilities in childhood and puberty, stabilizing after about two decades of life to explain roughly two-thirds of the variance. The remaining third of the variance was explained by environmental influences. The effect of shared environmental influences on cognitive abilities decreased greatly until the age of 30, whereas nonshared environmental influences increased slightly but continuously into late adulthood. The authors assumed that genetic effects in early life get stronger with age, whereas shared environmental influences weaken as individuals choose their own environments and become more and more independent of their parental home. In summary, such results are often interpreted in such a way that the "heritage" of one's family lies in one's genetic makeup, whereas the effects of the shared environment diminish when the individual

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matures. Increases in genetic effects can also be the result of active genotype-environment correlations, which occur when individuals actively select environments that fit their genetic endowment (Scarr & McCartney, 1983).

By contrast, the meta-analysis also revealed that the heritability of personality traits slowly decreased with age, whereas nonshared environmental influence increased, both stabilizing only after middle adulthood. Genetic influences explained 40%–50% of interindividual differences in personality, whereas the remaining 50%–60% were due solely to nonshared environmental influences.

We aim to examine the relative contributions of genetic and environmental influences on self-control in adolescence and young adulthood and compare our results with the trajectories of these influence characteristics of the cognitive and personality perspectives on self-control in order to determine which of these perspectives better accounts for the data. Before doing so, we present the current state of behavior genetic research regarding self-control.

A recent meta-analysis of $k = 31$ studies on genetic influences on self-control found an overall broad-sense heritability (additive and nonadditive genetic influences) of 60% for mostly self-reported self-control, suggesting a robust genetic effect (Willems et al., 2019). However, the heritability estimates ranged from 0% to 90% across studies. This heterogeneity regarding the importance of genetic influences mirrors contrasting positions in the nature-nurture debate. Therein, some researchers have concluded that strong genetic effects exist, neglecting the impact of the environment on self-control (e.g., Beaver, Eagle Schutt, et al., 2009; Wright et al., 2008), whereas others have attributed individual differences in self-control mainly to parental socialization and have disregarded genetic endowments (e.g., Gottfredson & Hirschi, 1990).

Even though most of the studies included in the meta-analysis used self-report measures to determine self-control (e.g., low self-control scales in the Add Health data, for details, see Beaver, Ratchford, & Ferguson, 2009), the authors also found a couple of studies that used observed behavior (e.g., delay of gratification tasks, $k = 5$) or executive functioning measures (e.g., a version of the Stroop task, $k = 1$). Contrary to common expectations, various investigations have revealed a clear distinction between executive functions and self-report measures of self-control (Nęcka et al., 2018; Saunders et al., 2018; Wennerhold & Friese, 2020) and only weak correlations between behavioral assessments and questionnaire measures of self-control (Eisenberg et al., 2019). Furthermore, in the meta-analysis by Willems et al. (2019), the informant emerged as a significant moderator of the heritability of self-control with higher heritability estimates for parent reports (75%) than for self-reports (53%) or observations (41%). The heterogeneity in heritability estimates might therefore also be due to different measurements used in the primary studies (i.e., by self-report vs. behavioral observation vs. executive function task) stemming from different perspectives on self-control.

Willems et al. (2019) found no significant moderation effect of linear age on the heritability of self-control, but inspecting the results more closely, an increase in heritability from early childhood (0 to 6 years, $h^2 = 0.46$) to middle childhood (7 to 12 years, $h^2 = 0.70$) was evident, followed by a slight decrease in adolescence (13 to 18 years, $h^2 = 0.58$) and potential stability in adulthood (18+ years, $h^2 = 0.60$).[5] The authors assumed that these differences in heritability estimates could be attributed to differences in informants rather than differences in age. By applying the same instrument to assess self-control in all age groups, our study focuses on age differences and controls for different informants and different measures.

The meta-analytic results by Willems et al. (2019) provide no clear support for either of the two perspectives (personality vs. cognition; Briley & Tucker-Drob, 2017) which might be reconciled by the Theory of Personality Coherence (Caspi & Moffitt, 1993). Caspi and Moffitt suggested that individual differences are accentuated in periods of change and insecurity, which can be observed in higher cross-sectional variance during these periods. Puberty is a critical period of change from immaturity and dependence to maturity and independence (Spear, 2007). Accordingly, in puberty, we would expect higher variances in traits such as self-control. Furthermore, the accentuation of individual differences may be reflected in augmented heritability estimates because, in novel and unstructured situations, people tend to behave based on their early genetic predispositions. Therefore, the peak of heritability estimates, Willems et al. (2019) found for middle childhood (defined as the age span from 7 to 12 years), could be the result of the beginning of developmental maturation accompanied by accentuated genetic predispositions.

In sum, differences in the patterns of relative genetic and environmental influences on the development of self-control might depend on the specific criterion that is being investigated (cognitive abilities or personality characteristics). We have presented three theoretical perspectives that all seek to explain changing patterns in genetic and environmental influences on differences in self-control from childhood to adulthood (cognitive and personality perspectives: Briley & Tucker-Drob, 2017; Theory of Personality Coherence: Caspi & Moffitt, 1993). These patterns served as points of reference for the examined etiology of self-control with regard to the age groups we assessed. With respect to the multiple possibilities to assess self-control, one suitable explanation for the great range of heritability estimates included in Willems et al. (2019) may also reflect the type of measurement. Because

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different types of measurement capture different aspects of self-control, in the present study, we used the same measure of self-control in all age groups. This measure combines self-report items for assessing the consistency of interest (grit) and self-control. Both of these constructs have shown considerable positive correlations with the personality dimension conscientiousness and emotional stability (Rimfeld et al., 2016; Tangney et al., 2004).

1.2 | The role of specific environmental conditions

We consider the inspection of specific environmental influences on self-control to be just as important as the investigation of genetic effects. An abundance of studies have shown substantial correlations between self-control and specific environmental factors including parental socioeconomic status (e.g., Evans et al., 2005) a chaotic home environment (e.g., Holmes et al., 2019), and parenting style (e.g., Li et al., 2019). Taking these factors into account extends the meta-analytic findings of Willems et al. (2019) by focusing not only on the heritability of self-control but also considering various factors that may constitute environmental influences of self-control.

Higher family income, an important aspect of socioeconomic status, is associated with better delay of gratification in schoolchildren and better teacher reports of children's self-control (Evans et al., 2005; Evans & English, 2002; Evans & Rosenbaum, 2008). Furthermore, along with other constructs, parental education and occupational status can explain unique variance in 3-year-old children's self-control measured by parent reports (Ng-Knight & Schoon, 2017). Related, but not equivalent to socioeconomic status, is the quality of the home environment, often captured by the Confusion, Hubbub, and Order Scale (CHAOS; Matheny et al., 1995). CHAOS refers to the degree of environmental confusion, such as noise, crowding, and disorder in a household. Higher CHAOS is associated with more conduct problems in children, higher parental stress, and adverse parenting behaviors, such as high parental negativity and low warmth toward the child (Deater-Deckard et al., 2009). Socioeconomic status and CHAOS are related to each other in a manner that the home environment in low-income families is more chaotic and shows less routine than in high-income families (Vernon-Feagans et al., 2016). Both low socioeconomic status and high CHAOS in a family were found to hamper children's normative development of self-control during middle and late childhood, subsequently favoring more risk-taking behaviors during adolescence (Holmes et al., 2019).

With reference to parenting, a meta-analysis of $k = 191$ articles revealed the bidirectional effect between parenting and self-control in adolescents aged 10–22 years (Li et al., 2019). The authors differentiated between positive and negative parenting as well as the parent–child relationship. Positive parenting (e.g., parental warmth, monitoring, and positive control) is believed to enhance self-control in children, whereas harsh, inconsistent negative parenting with psychological negative control is believed to produce the opposite effect and hinder the development of self-control (Eisenberg et al., 2005; Finkenauer et al., 2005; Li et al., 2019). Additionally, we have to consider that parent–child interactions are bidirectional. Adolescents' behavior can also evoke different parental reactions, for example, children with low self-control may evoke more negative reactions and harsh control in their parents. This effect refers to an evocative or reactive genotype-environment correlation, which results when individuals, on the basis of their genetic endowment, evoke specific reactions from their environment.

In behavior genetic analyses, the measurement of constructs plays an important role. Both socioeconomic status and chaotic home environment are often assessed on the family level resulting in identical values for both twins. To estimate genetic and environmental influences on a variable, however, twin-specific evaluations are necessary. Since in our study, socioeconomic status was assessed on the family level, the focus of behavior genetic decompositions lay on the chaotic home environment and parenting styles, which were measured for each twin separately.

Children's self-control seems to be positively related to higher parental socioeconomic status, an ordered home environment, and a positive, warm parenting style. An interesting but often overlooked factor is that parents' resources may be distributed differentially between children, and therefore, socioeconomic status or parenting influences might not be identical across siblings, or in this case, between twins (Conley, 2008). Depending on the parenting strategy, parents might invest in offspring who appear to be most able, thereby producing an inequality-reinforcing effect, or they might make compensatory investments in their less endowed child to equalize their children's chances. Furthermore, it is important to take into account that siblings might not perceive their parents or their home environment in the same way. Even though a chaotic home environment might be objectively the same for both twins, their perceptions of noise and order may differ.

Most studies investigating environmental influences on self-control have focused exclusively on the environment and did not consider genetic effects. Behavior genetic analyses bring together genetic and environmental influences and thereby offer a unique opportunity to gain more comprehensive insights into the development of self-control. In this spirit, the present study investigates

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whether parenting style and CHAOS act as shared and/or nonshared environmental influences on self-control, that is, whether they contribute to similarity or dissimilarity among children reared in the same family.

2 | HYPOTHESES

The aim of this study was to investigate the etiology and the phenotypical development of self-control in adolescence and young adulthood. On a phenotypic level, given that delay of gratification increases and impulsive behavior diminishes from age 10 to age 30 (Steinberg et al., 2008, 2009), we first expected higher mean-level self-control with increasing age in our age groups. Second, due to the relation between self-control and personality traits, we expected higher 1-year stabilities of self-control from our youngest age group up to our oldest, just as has been found for personality traits (McCrae & Costa Jr., 1994; Roberts & DelVecchio, 2000).

In terms of behavior genetic analyses, we hypothesized decreasing genetic and increasing nonshared environmental influences on self-control across the age groups from 13 to 25; shared environmental influences were not expected to contribute significantly to self-control. To develop these hypotheses, we relied on the positive correlation between our measure of self-control and the personality dimension conscientiousness and emotional stability (Rimfeld et al., 2016; Tangney et al., 2004) and accordingly referred to both the personality perspective presented by Briley and Tucker-Drob (2017) and the Theory of Personality Development (Caspi & Moffitt, 1993), which ties in with meta-analytic results by Willems et al. (2019). Additionally, regarding environmental influences, we expected socioeconomic status, parenting style, and CHAOS to be phenotypically related to self-control in such a manner that higher socioeconomic status, a positive parenting style, and an orderly home environment would go along with better self-control (e.g., Holmes et al., 2019; Li et al., 2019). In contrast to socioeconomic status assessed at the family level, resulting in one score for the whole family, perceptions of CHAOS were captured for each individual separately and thereby offered the opportunity to investigate differences between family members. Therefore, we further analyzed CHAOS and parenting style in twin difference models, focusing on testing the presence of nonshared environmental effects.

3 | MATERIALS AND METHODS

We preregistered our analyses in the *Open Science Framework* (https://osf.io/sf7q2/). Minor deviations from the preregistered analyses are outlined in the following. Regarding the measurement instruments, we excluded the first item from the CHAOS scale because it was not assessed in Age Group 3, and we used factor analysis to classify parenting style into two factors (positive and negative parenting). Missing values on all items except self-control were imputed with Full Information Maximum Likelihood (FIML). With reference to the analyses, we moved our second research question on the compensating effect of socioeconomic status to a subsequent manuscript, and we decided to take a closer look at the twin-specific reports on parenting style and CHAOS in the current study. Deviations are fully described in a commented version of the preregistration on the *Open Science Framework*.

3.1 | Data

The sample consists of data from the first two waves of the German twin family study *TwinLife*, a longitudinal cohort-sequential study comprising four age groups of same-sex twins and their families (Hahn et al., 2016; Mönkediek et al., 2019). The *TwinLife* panel is based on a national probability sample and covers a large age span ranging from early childhood to young adulthood as well as the whole distribution of educational, occupational, and income structures in Germany (Lang & Kottwitz, 2017). Since 2014, personal face-to-face interviews and intermediate telephone interviews have been carried out in alternating 1-year intervals. The first wave was conducted in 2014/2015, beginning with a personal assessment. *TwinLife* covers a wide age span that ranges from early childhood to young adulthood. In the youngest age group (Age Group 1), parents rated their children's self-control; in the older age groups, self-control was assessed by self-reports. Different informants might confound the results, so we decided to restrict our analyses to the three older age groups (year of birth Age Group 2: 2003/2004; Age Group 3: 1997/1998; Age Group 4: 1991/1992). Data on self-control were collected in the first telephone interview and the second face-to-face interview; socioeconomic status, CHAOS, and parenting style were only assessed in the first face-to-face interview. We analyzed the data on self-control cross-sectionally with respect to the second face-to-face interview and longitudinally by computing correlations between the first telephone interview and the second face-to-face interview to obtain 1-year stabilities. All questionnaires and items are accessible online on the *TwinLife* page of the GESIS Data Catalogue (10.4232/1.13539; Diewald et al., 2020) and in the supplements of the current study (see Table S1).

Our reference data set (second face-to-face interview 2017) includes 2007 twin families (Mönkediek et al., 2019).

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We excluded twins without zygosity information and twins who had answered fewer than four of the six self-control items. Based on our inclusion criteria, the final data set comprised 3354 twins; 1337 twins in Age Group 2 (M = 13.00 years, SD = 0.34), 1098 twins in Age Group 3 (M = 19.01 years, SD = 0.38), and 919 twins in Age Group 4 (M = 24.99 years, SD = 0.84). For our main measure of self-control, Age Group 2 includes n = 622 complete twin pairs (MZ = 256, DZ = 366), Age Group 3 n = 501 (MZ = 243, DZ = 258), and Age Group 4 n = 379 (MZ = 203, DZ = 176). We matched data from the first face-to-face interview (2 years earlier) and the first telephone interview (1 year earlier) to this data set. An overview of the informants and number of items for each scale is provided in the supplements (see Table S2).

3.2 | Measurements

3.2.1 | Self-control

Self-control was assessed with a set of six items from two different scales for measuring the consistency of interest (a subscale of grit) and self-control. All items were rated on a 5-point rating scale (1 = *strongly disagree* to 5 = *strongly agree*). Consistency of interest was measured with three items from the German translation of the Consistency of Interest Scale (e.g., “New ideas and projects sometimes distract me from previous ones”; Fleckenstein et al., 2014; originally: Duckworth et al., 2007). Self-control was assessed with three items from the German short version of the Self-Control Scale (e.g., “I do certain things that are bad for me, if they are fun”; Bertrams & Dickhäuser, 2009; originally: Tangney et al., 2004). The validity of the self-control measure was assessed by factor analyses and correlations with external scales. Having a large sample size, a Kaiser–Meyer–Olkin index of KMO = 0.78 and a significant Bartlett's sphericity test ($\chi^2(15) = 2597.87$, $p < 0.001$), prerequisites to run a principal component analysis, were fulfilled. An exploratory factor analysis of the six items revealed a one-factor structure that explained 40% of the variance with an eigenvalue of 2.38. Additional parallel analysis indicated that one eigenvalue, or factor, from the raw data was above the 95th percentile based on the Monte Carlo simulation. Five out of six items loaded with 0.58 or higher on the factor (see Supplements Table S3 for factor loadings). Although one item (“I become interested in new pursuits every few months”) loaded only with 0.29 on the factor, we decided to include all six items in our analysis of self-control, based on the suggestion of a one-factor structure given by the factor analyses and the fact that excluding the item did not change study results significantly. For the twin difference models, all six items were averaged per twin, for the latent analyses (mean development, rank-order stability, measurement invariance, and heritability of self-control), we used raw item values. In general, higher values indicate better self-control. The internal consistencies of self-control were $\alpha = 0.68$ in the second face-to-face interview and $\alpha = 0.61$ in the first telephone interview. Construct validity was confirmed by latent correlations between self-control and the scales associated with self-control in previous studies (e.g., Tangney et al., 2004). As expected, self-control was positively correlated with conscientiousness ($r = 0.51$, $p < 0.001$) and self-esteem ($r = 0.29$, $p < 0.001$) and was negatively correlated with neuroticism ($r = -0.41$, $p < 0.001$) and internalizing problem behavior ($r = -0.22$, $p < 0.001$).

3.2.2 | Socioeconomic status

Three indicators represented socioeconomic status: parental education, parental occupation, and family net income. *Parental education* was measured with the International Standard Classification of Education (ISCED; Schneider, 2008). *Parental occupation* was assessed with the International Socioeconomic Index of Occupational Status (ISEI; Ganzeboom et al., 1992), and the Erikson–Goldthorpe–Portocarero Class Schedule (EGP; Erikson et al., 1979). We determined ISCED, ISEI, and EGP for each parent. *Family net income* was assessed with the Organization for Economic Cooperation and Development (OECD) modified equivalence scale (for a detailed description, see Hagenaars et al., 1998). The indicators were integrated into a composite factor score derived from a confirmatory factor analysis (for details, see Gottschling et al., 2019). Higher values indicate higher socioeconomic status.

3.2.3 | Chaotic home environment (CHAOS)

CHAOS refers to bad family functioning and describes a noisy and crowded situation at home accompanied by little routine. To measure CHAOS, the German short version of the Chaos, Hubbub, and Order Scale was applied (Hanscombe et al., 2011; originally: Matheny et al., 1995). The first item (“I [used to] have a regular bedtime routine”) was not assessed in the third age cohort; therefore, our scale consisted of five items (e.g., “It's a real zoo in our home”) rated on a 5-point rating scale (1 = *strongly disagree* to 5 = *strongly agree*) and aggregated into a mean score. Twins who no longer lived at home were interviewed retrospectively and asked to indicate to what extent the statements described their home when they were still living at home. Higher values indicate more CHAOS. The internal consistency of the CHAOS score across all age groups was $\alpha = 0.66$.[6]

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3.2.4 | Parenting style

The parenting style assessment was adapted from the Panel Analysis of Intimate Relationships and Family Dynamics (pairfam; Huinink et al., 2011). Twins rated a total of 13 items that referred to the subjectively experienced frequency of emotional warmth (4 items), psychological control (3 items), negative communication (2 items), monitoring (2 items), and inconsistency (2 items) with respect to both their father's and their mother's behavior (e.g., "How often does your mother/father praise you?"). Responses were given on a 5-point rating scale (1 = *never* to 5 = *very often*). For participants older than 18, items were reformulated to assess parenting retrospectively ("Recall the time when you lived with your parents or the time before your 18th birthday. How often did the following things typically happen between you and your mother/father?"). For the present analyses, we averaged the scores between the two parents.

Previous research proposed that parenting items can be assigned to two analytically distinct parenting factors: positive and negative parenting (Coldwell et al., 2006). Our study revealed a similar pattern. An exploratory factor analysis of all the parenting items revealed two independent factors that explained 49% of the variance with eigenvalues of 3.78 (Factor 1) and 2.56 (Factor 2). According to the Kaiser–Guttman criterion, a third factor with an eigenvalue of 1.17 was substantial, too. However, when we checked the scree plot, we identified a distinct break in the slope that suggested two factors. According to the varimax-rotated two-factor solution, we labeled these factors "positive" and "negative" parenting. Positive parenting is composed of emotional warmth and monitoring, whereas negative parenting refers to psychological control, negative communication, and inconsistency. Higher values indicate more positive (negative) parenting behavior. Internal consistencies across all age groups were $\alpha = 0.82$ for a positive and $\alpha = 0.73$ for a negative parenting style.

3.3 | Analytic strategy

We used Mplus (Version 8.2; Muthén & Muthén, 2017) to conduct all analyses and Full Information Maximum Likelihood (FIML) to handle missing data. The first set of analyses used latent self-control factors to control for measurement error. Therein, we estimated the relevant parameters (A, C, D, and E) by employing univariate twin models in a multigroup analysis. In the second set of analyses, we used manifest factors to investigate the potential environmental influences in twin difference models.

Overall model fit was evaluated with the chi-square statistic (χ^2) in combination with two further criteria: the root mean square error of approximation (RMSEA) and the comparative fit index (CFI), for which RMSEA < 0.08 and CFI > 0.90 indicate an acceptable model fit (Browne & Cudeck, 1992; Hu & Bentler, 1999). Nested models were compared using Likelihood Ratio Tests (differences in χ^2 values between two nested models) with a significant *p*-value ($p \leq 0.05$) indicating significant differences between models.

Measurement invariance is critically important when comparing different age groups. If measurement invariance is not established first, between-group differences cannot be interpreted in an unbiased way. To model the latent self-control factor, we included the six respective items, fixing one path to one and allowing the other paths to vary. After equalizing the paths for pairs of twins, and further, for MZ and DZ twins, to test whether these groups could be compared, we checked for measurement invariance across age groups. We conducted equivalence tests to compare the model fit of metric and scalar measurement invariance models with the model fit of the unconstrained model. Metric measurement invariance is obtained when factor loadings can be equalized between groups without a loss of model fit, and scalar measurement invariance indicates that the same applies when additionally, intercepts of the manifest items are set to be equal. As the χ^2 statistic depends on the sample size and provides a very sensitive statistical test, practical fit indices are used to evaluate measurement invariance such that overlapping 90% RMSEA confidence intervals (CIs) and differences in CFI values < 0.01 indicate acceptable measurement invariance (Cheung & Rensvold, 2002; MacCallum et al., 1996).

Data were analyzed longitudinally by means of 1-year correlations and cross-sectionally by assessing patterns of means and variances in the three age cohorts. For the cross-sectional analyses, we analyzed data from the second face-to-face interview.

3.3.1 | Means and rank-order stability

Differences between age groups in mean-level self-control as well as the 1-year stability (between the first telephone interview and the second face-to-face interview) of self-control were examined in multiple group analyses with Likelihood Ratio Tests.

3.3.2 | Behavior genetic analyses

According to Visscher et al. (2008), there is no design for optimizing the detection of A and C simultaneously because A and C have different optimum proportions of MZ twins that need to be detected. As a practical compromise, the authors suggested that researchers use approximately

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the same numbers of MZ and DZ twin pairs. We did so in our sample. Furthermore, sample size matters for detecting effects of A, C, and E. With around 1000 twins in each sample, the sample sizes appeared to be sufficient to discover small effects of A and E (Visscher et al., 2008). However, to detect small effects of C, very large sample sizes are required. Based on the authors' results, to detect C effects of 0.15 or larger with 80% power at a Type I error rate of 0.05, a sample of 1000 twins is required. With our sample of around 1000 twins in each age group, we could therefore only expect to find C effects with 80% power, when they are at least 0.15 or larger.

To estimate the relevant parameters (A, C or D, and E), we relied on the classical twin design (CTD) and fit quantitative genetic structural equation models (SEM). With our information about MZ and DZ twins reared together, we could not fit a model with additive genetic, genetic dominance, and shared environmental effects simultaneously. However, we could either fit ACE or ADE models and reduce them to obtain the most parsimonious model (for details, see Knopik et al., 2017). As mentioned before, comparing MZ and DZ twin correlations can indicate which parameters are likely to explain the variance in a trait. Usually, ACE models, including additive genetic, shared environmental, and nonshared environmental influences, are fit. MZ twin correlations more than twice as large as DZ twin correlations may suggest genetic dominance effects, so an ADE model can be fitted instead. ADE models include additive genetic, genetic dominance, and nonshared environmental influences. In the next step, we compared the full ACE or ADE model to the nested models that resulted from fixing one or more of the variance components to zero. If the reduced model fits the data as well as the full model does, the more parsimonious model is preferred. This procedure was applied to all age groups separately.

3.3.3 | Specific environmental influence on self-control

In order to get a first overview, we identified latent correlations between all study variables. In three steps, we further investigated how socioeconomic status, CHAOS, and parenting style are related to self-control and whether they “act” as shared and/or nonshared environmental sources. These analyses were conducted separately for each age group. In the first step, we calculated family means for all variables by averaging the scores of the twins in one family. We correlated the family means for socioeconomic status, CHAOS, as well as positive and negative parenting with the family means for self-control to test whether twins' mean self-control depends on these environments. Second, we calculated differences in self-control between each pair of twins and correlated them with the family means for socioeconomic status, CHAOS, and parenting style. We, therein, analyzed whether twins are more similar or different along an environmental continuum. These correlations can help clarify whether parental resources are distributed equally between twins. Third, we tested specifically for nonshared environmental influences in twin difference models (Pike et al., 1996). This model controls for the shared environment by using differences between twins, assuming that the shared environment leads to similarity and therefore has no impact on differences. Because socioeconomic status was assessed at the family level, we were not able to analyze differences between twins and had to exclude the construct from twin difference models. We investigated whether differences in parenting style or CHAOS were associated with differences in self-control. Investigating differences in monozygotic and dizygotic twins separately (later referred to MZ and DZ models) provides a way to observe nonshared environmental and genetic influences independently: A significant correlation between differences within monozygotic twins cannot be explained by shared genes or by a shared environment and would therefore suggest nonshared environmental influences as the main underlying source of the relation between parenting style/CHAOS and self-control. Furthermore, a significant correlation between differences in dizygotic twins that is not present in monozygotic twins is indicative of the importance of genetic influences on the association between parenting style/CHAOS and self-control. To be able to better interpret the direction of effects, we used absolute differences within each twin pair.

4 | RESULTS

4.1 | Means and rank-order stability

Analyses of measurement invariance of self-control across age groups revealed metric measurement invariance between all age groups, indicating that the factor loadings could be equalized between age groups without a significant loss of model fit. In the next step, we additionally equalized the intercepts of the manifest self-control items to check for scalar measurement invariance. Between Age Groups 2 and 3, we found partial scalar measurement invariance with two intercepts set free ($\chi^2 = 135.11$, $df = 26$, $RMSEA = 0.059$; $CFI = 0.953$). Between Age Groups 3 and 4, we also identified partial scalar measurement invariance with one intercept set free ($\chi^2 = 127.69$, $df = 27$, $RMSEA = 0.061$; $CFI = 0.946$). Partial scalar measurement invariance refers to factor loading invariance and partial

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intercept invariance. Accordingly, we could compare the self-control means between these age groups directly because the latent variables represent equivalent constructs. For Age Groups 2 and 4, we would have had to set free at least three intercepts to assume partial scalar measurement invariance (χ^2 = 138.72, df = 25, $RMSEA$ = 0.064; CFI = 0.939). As we could not assume partial scalar measurement invariance with half of the intercepts set free, we decided not to compare Age Groups 2 and 4 directly. Model fit indices for all age groups are provided in the supplements (see Table S4).

Sample and descriptive statistics are presented in Table 1. In Age Group 3, manifest mean self-control (M = 2.76) appeared to be lower than in the other age groups. To control for measurement error, we compared the latent self-control means in multigroup analyses.[7] Overall, differences in self-control between groups were small. Nevertheless, similar to the manifest means (see Table 1), we detected a decrease in latent mean-level self-control from 13 to 19 years ($\Delta M = -0.10$, $p = 0.036$) and another significant increase from 19 to 25 years ($\Delta M = 0.27$, $p < 0.001$). As we report standardized results, these differences represent small effect sizes sensu Cohen (1992). In sum, mean self-control decreased only slightly from ages 13 to 19 and increased from ages 19 to 25.

As expected, the latent 1-year stability of self-control increased across age. Chi-square difference tests revealed that the increase was significant from ages 13 to 19 (from 0.55 to 0.86; $\Delta\chi^2$ = 27.16; Δdf = 1, $\Delta p < 0.001$) but not from ages 19 to 25 (from 0.86 to 0.93; $\Delta\chi^2$ = 0.20; Δdf = 1, Δp = 0.655). These results suggest a high degree of stability for self-control between the face-to-face assessment and the telephone interview 1 year later. This stability increased with age, and it reached a plateau in young adulthood.

4.2 | Behavior genetic analyses

Manifest intraclass correlations (ICCs) for self-control are presented in Table 2. Scalar measurement invariance was given for zygosity (MZ and DZ) as well as birth order (firstborn, second born twin). MZ twin intraclass correlations exceeded the DZ twin intraclass correlations in all age groups, indicating genetic effects. Since MZ twin ICCs were more than twice the DZ twin ICCs, nonadditive genetic instead of shared environmental influences were considered. The ICCs for the MZ twins increased continuously across age groups (from 0.34 to 0.54), indicating that MZ twins became more similar with age. The ICCs for the DZ twins were particularly low in Age Group 3 (ICC = 0.07, p = 0.117) compared with the other age groups (2, ICC = 0.14, p = 0.003; Age Group 4: ICC = 0.18,

TABLE 1 Sample and descriptive statistics

	Sample statistics						Descriptive statistics M (SD)				
	N										
Age group	Monozygotic twins	Dizygotic twins	Female	Male	All	Age M (SD)	Self-control	CHAOS	Positive parenting	Negative parenting	SES
2	547 (41%)	790 (59%)	667 (50%)	670 (50%)	1337	13.00 (*0.34*)	2.87 (*0.68*)	2.07 (*0.72*)	3.89 (*0.58*)	2.29 (*0.60*)	0.17 (*0.88*)
3	552 (48%)	576 (53%)	545 (41%)	644 (59%)	1098	19.01 (*0.38*)	2.76 (*0.71*)	2.14 (*0.74*)	3.50 (*0.69*)	2.39 (*0.58*)	0.13 (*0.89*)
4	482 (52%)	473 (48%)	381 (42%)	538 (59%)	919	24.99 (*0.84*)	2.89 (*0.67*)	2.03 (*0.73*)	3.68 (*0.69*)	2.39 (*0.57*)	0.10 (*0.87*)
All	1551 (46%)	1803 (54%)	1852 (55%)	1502 (45%)	3354	18.25 (*4.89*)	2.84 (*0.69*)	2.08 (*0.73*)	3.71 (*0.67*)	2.35 (*0.59*)	0.14 (*0.88*)

Note: Manifest means and standard deviations (printed in italics).

Abbreviation: SES, socioeconomic status.

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TABLE 2 Latent variance components and manifest intraclass correlations for self-control

Age group	Manifest ICCs		Total variance	Model	Free total variances		Equalized total variances	
	MZ	DZ			D	E	D	E
2	0.34 [0.232; 0.448]*	0.14 [0.042; 0.242]*	0.34 [0.289; 0.393]	Unstand	0.16 [0.108; 0.212]	0.18 [0.128; 0.232]	0.18 [0.123; 0.233]	0.19 [0.138; 0.248]
				Stand	0.47 [0.338; 0.604]	0.53 [0.396; 0.662]	0.48 [0.346; 0.613]	0.52 [0.387; 0.654]
3	0.42 [0.313; 0.520]*	0.07 [−0.048; 0.194]	0.41 [0.350; 0.479]	Unstand	0.22 [0.155; 0.291]	0.19 [0.131; 0.250]	0.20 [0.140; 0.250]	0.18 [0.123; 0.229]
				Stand	0.54 [0.408; 0.672]	0.46 [0.328; 0.592]	0.53 [0.394; 0.658]	0.47 [0.342; 0.606]
4	0.52 [0.408; 0.610]*	0.18 [0.034; 0.320]*	0.37 [0.303; 0.432]	Unstand	0.28 [0.210; 0.345]	0.09 [0.039; 0.135]	0.28 [0.225; 0.341]	0.09 [0.040; 0.136]
				Stand	0.76 [0.636; 0.887]	0.24 [0.113; 0.364]	0.76 [0.638; 0.887]	0.24 [0.113; 0.362]

Abbreviations: D, genetic variance; DZ, dizygotic twins; E, nonshared environmental variance; ICC, intraclass correlation; MZ, monozygotic twins; stand, standardized model; unstand, unstandardized model.

*$p < 0.01$.

$p = 0.008$), pointing to the tendency for DZ twins to drift apart slightly in late adolescence and become more similar again in young adulthood.

Based on the ICCs, we fit multigroup ADE models to all age groups. In Age Groups 2 and 4, either A or D could be dropped without worsening the model fit significantly. In Age Group 3, only A could be dropped; dropping D resulted in a loss of model fit ($\Delta\chi^2 = 4.30$; $\Delta df = 1$, $p = 0.038$). Fit statistics and model comparisons are presented in the supplements (see Table S5). Consequently, we decided to further analyze the more parsimonious DE models in all age groups to compare results across age better. Results of the full ADE models are given in the supplements (see Table S6). Variance components of the final DE models are presented in Table 2. When dropping A or D, the variance of the dropped parameter merges to the other one. Since the modeled D parameters at ages 13 and 25 also contain parts of A, heritability was understood in a broad sense and defined as the ratio of total genetic variance to total phenotypic variance. In the following, D effects are referred to genetic effects in general.

Figure 1 shows the percentages of D and E influences on self-control with the total variances being free (left) versus equalized (right) across the three age groups. As depicted in Figure 1 on the left, the total variance appeared to be higher in Age Group 3 ($s^2 = 0.41$) than in the other two age groups (Age Group 2: $s^2 = 0.34$; Age Group 4: $s^2 = 0.37$). At age 19, differences in self-control seemed to be pronounced compared with the other age groups, which may point to increased genetic influences in transition periods as proposed by Caspi and Moffitt (1993). Comparing Age Group 2 versus 3, we observed some decline in model fit when the total variances were equalized. However, equalizing the total variance across all age groups did not significantly impair the model fit ($\Delta\chi^2 = 5.72$; $\Delta df = 2$, $p = 0.057$) and variance components did not differ substantially when equalizing the overall variance. Models with equalized total variances and models with free total variances showed increasing genetic effects on self-control (from 47%/48% to 76%) and, accordingly, decreasing nonshared environmental influences across all age groups. When comparing the 13- and 19-year-old twins, the difference in DE parameters was small and not significant for the model with free total variances ($\Delta\chi^2 = 4.47$; $\Delta df = 2$, $p = 0.107$), but between 19 and 25 years of age, the DE parameters differed significantly ($\Delta\chi^2 = 8.94$; $\Delta df = 2$, $p = 0.014$).

In sum, we observed a significant increase in genetic influences and decreasing nonshared environmental influences on self-control from late adolescence (age 19, Age Group 3) to young adulthood (age 25, Age Group 4). Particularly at age 19, genetic effects were substantially driven by a nonadditive genetic variance component.

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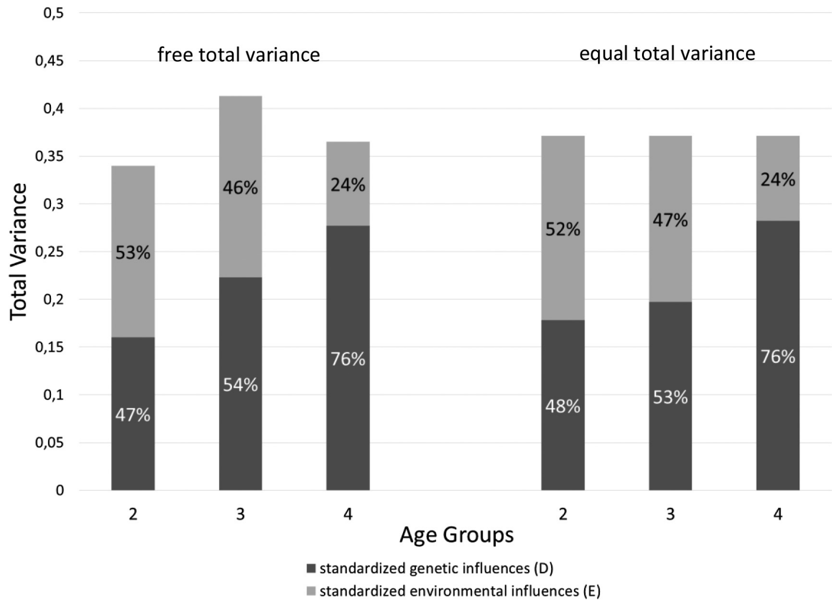

FIGURE 1 Percentages of change in genetic and nonshared environmental influences on self-control across age groups

Meanwhile, shared environmental influences were not present in the development of self-control in this age span. Age Groups 2 (age 13) and 3 (age 19) did not differ significantly in their genetic and environmental contributions to self-control. These results suggest that, from age 19 to age 25, genetic endowment becomes more relevant in explaining individual differences in self-control, whereas individual experiences become less important. These findings do not fit into the personality perspective depicted by Briley and Tucker-Drob (2017) and will be further discussed while taking into account the transition periods that Caspi and Moffitt (1993) suggested.

4.3 | Specific environmental influences

Regarding the manifest means in Table 1, in all age groups, the means for positive parenting were higher (M = 3.50 to 3.89) than the means for negative parenting (M = 2.29 to 2.39) or CHAOS (M = 2.03 to 2.14). Age Group 3 (19-year old) warrants particular attention because the mean perceived positive parenting (M = 3.50) was lower than for the other age groups, whereas the mean CHAOS was higher (M = 2.14). Perceived negative parenting showed its lowest mean in Age Group 2 (M = 2.29) and increased afterward, whereas families' socioeconomic status decreased across the age groups (from 0.17 to 0.10).

Latent correlations between all study variables are depicted in Table 3. As expected, self-control was negatively related to CHAOS ($r = -0.22$ to -0.28, $p < 0.001$) and negative parenting style ($r = -0.20$ to -0.23, $p < 0.001$). Slightly lower but still significant positive correlations were found between positive parenting style and self-control ($r = 0.13$ to 0.18, $p \leq 0.001$). Correlations with socioeconomic status were small and, except for Age Group 2 ($r = -0.08$, $p = 0.009$), nonsignificant.

CHAOS showed high interrelations with positive ($r = -0.44$ to -0.51, $p < 0.001$) and negative parenting styles ($r = 0.41$ to 0.49, $p < 0.001$) as well as moderate interrelations with socioeconomic status ($r = -0.10$ to -0.19, $p < 0.01$). Positive and negative parenting styles correlated between $r = -0.24$ and -0.31 ($p < 0.001$) with each other. Across age, we observed that self-control had lower correlations with CHAOS ($r = -0.22$, $p < 0.001$) and positive parenting ($r = 0.13$, $p = 0.001$) in Age Group 3 compared with the other age groups. Correlations between self-control and negative parenting remained largely stable (from $r = -0.23$ to -0.20), whereas correlations between socioeconomic status and CHAOS increased with age (from $r = -0.10$ to -0.19).

Correlations between self-control and specific environments on the family mean level were comparable to the correlations presented in Table 3. Differences in self-control along the environmental continuum of socioeconomic status, parenting style, and CHAOS revealed no significant effects. The perceived average socioeconomic status, parenting style, or CHAOS in one household did not affect differences in self-control between twins, but the more positive parenting and the less negative parenting and CHAOS, the more self-controlled were both children.

Mean absolute differences between twin pairs and intraclass correlation coefficients for all variables under study are provided in the supplements (see Table S7). Regarding the twin difference models (see Table 4), we found significant regression coefficients when predicting self-control from CHAOS and negative parenting style. In both "environments", only Age Group 3 revealed significant effects

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TABLE 3 Latent correlations

Variables	Age group 2					Age group 3					Age group 4				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1. Self-control	–					–					–				
2. CHAOS	−0.25**	–				−0.22**	–				−0.28**	–			
3. Positive parenting	0.16**	−0.44**	–			0.13**	−0.51**	–			0.18**	−0.46**	–		
4. Negative parenting	−0.23**	0.44**	−0.24**	–		−0.22**	0.49**	−0.31**	–		−0.20**	0.41**	−0.27**	–	
5. SES	−0.08**	−0.10**	0.06*	0.04	–	−0.05	−0.17**	0.08**	−0.02	–	0.03	−0.19**	0.17**	−0.07	–

Abbreviation: SES, socioeconomic status.

*$p < 0.05$; **$p < 0.01$.

TABLE 4 Twin difference models and manifest intraclass correlations

Age group	CHAOS						Negative parenting						Positive parenting					
	MZ model			DZ model			MZ model			DZ model			MZ model			DZ model		
	r	*β*	(SE)	*r*	*β*	(SE)	*r*	*β*	(SE)	*r*	*β*	(SE)	*r*	*β*	(SE)	*r*	*β*	(SE)
2	−0.15**	−0.03	*(0.06)*	−0.17**	−0.10	*(0.05)*	−0.15**	0.06	*(0.06)*	−0.18**	−0.09	*(0.05)*	0.14**	0.07	*(0.06)*	−0.09**	0.00	*(0.05)*
3	−0.29**	**−0.28****	*(0.06)*	−0.10**	0.03	*(0.06)*	−0.26**	**−0.16***	*(0.06)*	−0.17**	**−0.13***	*(0.06)*	0.06	−0.01	*(0.06)*	0.09*	−0.08	*(0.06)*
4	−0.18**	−0.09	*(0.07)*	−0.24**	**−0.28****	*(0.07)*	−0.20**	−0.09	*(0.07)*	−0.18**	−0.15	*(0.07)*	0.12**	0.07	*(0.07)*	0.15**	0.12	*(0.08)*

Note: Dependent variable is self-control, standardized coefficients; significant coefficients are presented in bold; *r* refers to intraclass correlation, *β* and (SE) describe weights and standard errors (printed in italics) of the twin difference models.

*$p < 0.05$; **$p < 0.01$.

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in MZ models (CHAOS: $\beta = -0.28$, $p < 0.001$; negative parenting: $\beta = -0.16$, $p = 0.011$). The effects in the MZ models were controlled for shared environmental and genetic influences and thus suggest that in late adolescence, the relation between self-control and CHAOS and the relation between self-control and negative parenting were mediated through nonshared environmental influences. The negative signs on the regression coefficients indicate that the child who reported less negative parenting and less CHAOS developed higher self-control, or conversely, the child who showed higher self-control reported less negative parenting and CHAOS. A positive parenting style revealed no significant effects in these models. Bearing in mind that twin difference models control for shared environmental and shared genetic influences, the nonsignificant relation between self-control and positive parenting could not be attributed to nonshared environmental influences but rather to the influences that were controlled for (shared genetic and environments).

5 | DISCUSSION

The present study aimed to address several questions regarding the etiology and the development of self-control in adolescence and young adulthood. We extended previous research on the heritability of self-control (Willems et al., 2019) by investigating a large representative sample and using the same measure of self-control in all age groups. Regarding the phenotypical development, we found a substantial increase in mean self-control from ages 19 to 25, and self-control appeared highly stable between the assessments, which were 1 year apart, reaching a plateau in young adulthood. As heritability estimates differ on the basis of the variance of a sample, large samples are required to obtain reliable estimations. Our large sample revealed increasing genetic influences on self-control, in particular from ages 19 to 25, and decreasing nonshared environmental influences. Although these results cannot be fully explained by the overall personality perspective by Briley and Tucker-Drob (2017), they suggest development in self-control that is comparable to the findings for conscientiousness.

Because the exclusive consideration of trait heritability is one sided and does not correspond with the current view that both genetic *and* environmental influences are substantial (Turkheimer, 2000), we further examined CHAOS and parenting style as potential specific environmental influences on self-control. Latent correlations turned out as expected, and twin difference models revealed that both CHAOS and negative parenting acted as nonshared environmental effects that contributed to individual differences between twins. In the following, we discuss our results in detail to integrate our study with previous phenotypical and behavior genetic analyses.

5.1 | Means and rank-order stability

We found a curvilinear pattern in mean self-control across age with a temporary dip in adolescence. According to prior findings, indicating that adults at the age of 30 show a better delay of gratification and lower impulsivity than young adolescents (Steinberg et al., 2008, 2009), we expected self-control to increase across age. The results for latent mean differences suggested a substantial increase from 19 to 25 years, the magnitude of which exceeded the decrease from 13 to 19 years. Overall, we can conclude that self-control is higher in adulthood than in adolescence. Some researchers have posited that personality development does not match the maturity principle, which assumes a linear increase in agreeableness, conscientiousness, and emotional stability with age (Denissen et al., 2013; Soto & Tackett, 2015). Instead, for conscientiousness, a personality trait that is closely related to self-control (Tangney et al., 2004), a negative age trend from late childhood into adolescence and a positive trend from adolescence into early adulthood was found (Soto et al., 2011). Although in their study, the negative peak in conscientiousness already appeared around 13–16 years, and their effects were somewhat stronger with a difference of 1/3 SD from childhood to adolescence and 2/3 SD from adolescence to young adulthood, the trend was comparable to the trend in self-control we found. Denissen et al. (2013) also suggested a curvilinear pattern for mean-level personality development, which they confirmed for conscientiousness. They assumed that self-regulatory mechanisms underlie personality development, and therefore, that the decrease in conscientiousness found for adolescents is the result of a divergence between a shift to higher standards by becoming older and the inability to comply with them because self-regulatory skills are underdeveloped. As many studies have proposed interventions to enhance self-control (de Ridder et al., 2020; Friese et al., 2017; Piquero et al., 2016), further research could identify the possible self-control mechanisms that underlie the development of conscientiousness.

Furthermore, the total variance in self-control appeared to be higher in 19-year-old twins (Age Group 3) than in the other age groups. Kandler et al. (2019) investigated personality development using *TwinLife* data and found a similar age trend for trait variance in conscientiousness. With regard to the Theory of Personality Coherence by Caspi and Moffitt (1993), individual differences in personality tend to be accentuated during the novel, ambiguous, and unpredictable life periods during which there

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is little information about which behaviors will be most adaptive. Transition periods should thus expand the variance within a sample. Emerging adulthood, originally defined by the period between 18 and 25 years of age, is characterized by higher demographic diversity and lower constraints regarding role requirements than other age periods (Arnett, 2000). To date, 20 years later, several sociodemographic changes in Germany are apparent, for example, that people tend to marry later and have children later. For example, women's mean age at first marriage increased from 28.4 years (31.2 for men) in 2000 to 31.7 (34.2) years in 2017 (Statistisches Bundesamt, 2019). In later work, Arnett mentioned that the age range from 18 to 25 is very conservative and that the end of emerging adulthood is highly variable and may be better defined by age 29, particularly on an international level (Arnett, 2014). Regardless of the explicit end of this period, there is a sociodemographic difference between adolescence, when the vast majority of people are unmarried and childless, and adulthood, when more people are married and have become parents. In between, there is emerging adulthood, which offers a large range of opportunities to develop individually and therefore represents a transition period according to Caspi and Moffitt (1993). In the present study, this transition postulated by Caspi and Moffitt could be seen in an accentuation of self-control variance. Furthermore, mean deviations in CHAOS and positive parenting support the idea of change with the beginning of emerging adulthood around age 19.

The increasing 1-year stability across our age groups fits a personality perspective on self-reported self-control. Personality traits show high cross-temporal stability (McCrae & Costa Jr., 1994; Roberts & DelVecchio, 2000). According to McCrae and Costa Jr. (1994), stability coefficients typically range from $r = 0.60$ to 0.80 over intervals up to 30 years, Roberts and DelVecchio (2000) found estimated trait consistencies ranging from $r = 0.47$ (12–17.9 years) to $r = 0.57$ (22 to 29 years) in their meta-analysis, which included a mean time interval of $M = 6.75$ (SD = 7.51). Our results indicated step-like increases in 1-year stability of self-control from $r = 0.55$ in young adolescence (13 years) to $r = 0.93$ in young adulthood (25 years). Higher stability values in our study could be attributed to the fact that we modeled latent variables and underpin the importance of using latent models to correct for measurement error. Since reliability estimates did not increase significantly across age, they could not explain the observed increasing stability (for details, see supplements Table S8). We can conclude that the 1-year stability of self-control increases in early life, particularly during adolescence, reaching a plateau in young adulthood. The time interval of 1 year we considered gives us an initial idea about the high level of stability self-control can reach. Nevertheless, it is important to investigate longer time periods and to figure out whether the stability of self-control changes again in later adulthood. Furthermore, future analyses should replicate the stability relying on the same method at any time of measurement. At the time of this study, *TwinLife* planned to assess self-control scales again in the fourth wave of face-to-face interviews in 2021. With such future data, studies could investigate self-control stability in a time interval of up to 5 years (from the first telephone interview to the fourth face-to-face interview).

5.2 | Behavior genetic analyses

After analyzing the phenotypical development of the mean levels and stability of self-control, we investigated the proportions of genetic and environmental influences across age. MZ and DZ twin correlations for self-control go along with meta-analytic results on self-report measures by Willems et al. (2019). They showed average twin correlations of $r = 0.48$ for MZ and $r = 0.18$ for DZ twins that differed significantly from those in parent reports. Higher similarities in parent than in self-reports could indicate that parents overestimate their twins' similarity according to assimilation effects proposed by Saudino et al. (2000). Furthermore, previous results on personality measures also showed low DZ twin correlations (Kandler et al., 2019; Polderman et al., 2015). There is the possibility of contrast effects deflating DZ twin correlations. Since those effects are more typically observed in parent reports than in twins' self-reports (Spinath & Angleitner, 1998), they may play less of a role in our data. The fact that our sample consists of same-sex twins only, should further reduce the probability of contrast biases (Asendorpf, 2001).

According to Briley and Tucker-Drob (2017), we expected decreasing genetic and increasing nonshared environmental influences on self-control across our age groups. Surprisingly, we found an increase in genetic influences on self-control, which was particularly strong from ages 19 to 25. Because Briley and Tucker-Drob (2017) analyzed overall personality in their study, such developmental differences between dimensions (e.g., conscientiousness or extraversion) may have been obscured. Findings from Willems et al. (2019) indicated an accentuation of the heritability of self-control in late childhood (7 to 12 years), which could be attributed to the transition into adolescence. We did not analyze twins younger than 13 and therefore could not identify changes in heritability estimates from late childhood to early adolescence. However, we identified emerging adulthood as a transition period according to Caspi and Moffitt (1993) beginning with increased variance at age 19. In addition to assuming more variance within a sample, Caspi and

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Moffitt (1993) also assumed that in transition periods, the genetic influences on behavior get stronger. The high total variance in 19-year-old twins and the strong genetic effects of 73% in 25-year-old twins could indicate that emerging adulthood begins with more total variance that is explained by both genetic and nonshared environmental influences and develops in terms of a greater relevance of genetic endowments. The importance of genetics and the nonshared environment for psychological traits during emerging adulthood was also shown in a recent analysis of data from the Twins Early Development Study (*TEDS*) by Rimfeld et al. (2021). The authors discuss the significant heritability in terms of possible gene-environment correlations and the role of nonshared environmental influences regarding idiosyncratic experiences that siblings make when they leave their family environment during emerging adulthood. To the extent that these results along with the findings reported here can be replicated longitudinally, emerging adulthood may be characterized as an important transition period in life in which early trait differences are accentuated. Accordingly, it is reasonable to assess such differences during this age period. Future projects will be able to draw on both *TwinLife* and *TEDS* data to conduct longitudinal analyses.

Another possible mechanism that may underlie increasing genetic effects on self-control involves the genotype-environment interplay. Our estimation of genetic and environmental influences is based on intraclass correlations for identical and fraternal twins. Looking more closely at the ICCs for self-control, MZ twins continuously became more similar, whereas DZ twins drifted apart slightly in late adolescence and became more similar again in early adulthood. Decreasing DZ similarity in *TwinLife* from the second to the third age group was also shown for conscientiousness by Kandler et al. (2019). A possible explanation for this pattern of results involves genotype-environment correlations, which can complicate the interpretation of genetic and environmental influences in classical twin designs if they contribute differentially to the resemblance between MZ and DZ twins. Genotype-environment correlations refer to correlations between experiences and genetic endowment, and there are three different types (Knopik et al., 2017). First, passive gene-environment correlations result from the passive inheritance of genes from parents to their children, which are related to the parental environment. Second, evocative gene-environment correlations refer to individuals evoking reactions from their environment due to their genetic endowment. Third, active gene-environment correlations occur when individuals seek or create environments that are correlated with their genetic propensities. To the extent that genotype-environment correlations are involved and based on the greater genetic similarity in MZ twins, it is possible that MZ twins react more similarly and search for more similar environments than DZ twins do (Plomin et al., 1977). As the importance of active gene-environment correlations increases from childhood to adolescence (Scarr & McCartney, 1983), adolescents may progressively create their own experiences in accordance with their genetic endowment, which can increase MZ twin resemblance and, as a consequence, heritability estimates. Further analyses should look for possible types of gene-environment correlations and their potential impact on heritability estimates.

Lastly, the substantial overlap between conscientiousness and self-control could indicate that genetic and environmental influences on these variables may also be shared. Therefore, future research should investigate whether the genetic and environmental effects that we found are specific to self-control or may be better explained by an overlap with personality traits.

5.3 | Specific environmental influences

Analyses of parenting style and CHAOS supported prior findings by indicating that an ordered home environment, high levels of positive parenting, and as little negative parenting behavior as possible are relevant to children's healthy self-control development (Eisenberg et al., 2005; Holmes et al., 2019; Li et al., 2019). We further expected that higher socioeconomic status would be related to higher self-control and the perception of a less chaotic home environment. The latter was confirmed in that children in families with higher socioeconomic status perceived less CHAOS, but surprisingly, we found only negligible correlations between self-control and socioeconomic status. One reason why we did not find a negative correlation between socioeconomic status and self-control as reported by Evans et al. (2005), Evans and English (2002) and Evans and Rosenbaum (2008) may involve the fact that they used a behavioral delay-of-gratification task and teacher reports to measure children's self-control at age 9. By contrast, we investigated self-control in self-reports of adolescents and young adults aged 13–25 years. Even though there was no direct relation between socioeconomic status and self-control in our study, higher CHAOS went along with both lower socioeconomic status and lower self-control. This could indicate a mediating effect of CHAOS on the relation between socioeconomic status and self-control, which was already found by Evans et al. (2005). Their results revealed that the effect of family income on teachers' ratings of children's self-control was mediated by mothers' CHAOS reports. Future research should test these findings with self-reported *TwinLife* data. Besides the fact that we used different measurement

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instruments, our sample also differed in age from Evans et al. (2005), Evans and English (2002) and Evans and Rosenbaum (2008). Therefore, another explanation for the nonsignificant correlation between self-control and socioeconomic status in our sample could be that as people grow out of childhood, self-control may be influenced more by subjective indicators of the family environment (e.g., CHAOS) and less prone to objective influences (e.g., family socioeconomic status). Thus, family socioeconomic status may become less relevant for individual self-control development with age. Nevertheless, we have to consider that age and informant may be confounded (see Willems et al., 2019) because the younger the children, the more likely external reports by parents or teachers are used. Therefore, future studies should disentangle the role of age and informant for the relationship between self-control and socioeconomic status.

Results from twin difference models suggest that different mechanisms are involved in explaining the relations between CHAOS, parenting style, and self-control. In adolescence, the relation between self-control and CHAOS as well as between self-control and negative parenting style appeared to be mostly mediated through nonshared environmental influences. For positive parenting style and self-control, we found a transmitting effect via shared genetic and/or environmental influences in all age groups. CHAOS describes a home environment that two twins share, and therefore, one might expect it to act as a "shared" environment, thus making twins more similar. However, the perception of CHAOS differed between twins such that the child who reported less negative parenting and less CHAOS showed higher self-control or the child who showed higher self-control reported less negative parenting and CHAOS. This underpins the importance of investigating the parts of twins' environments that are potentially "shared" in a way that opens up the possibility of identifying individual perceptions and interpreting them as nonshared environmental influences. Furthermore, these individual perceptions of family environments suggest that intervention studies may be more successful if they take place on the individual rather than on the family level. In general, it appears that beneficial environments (positive parenting) may be overall protective influences, whereas obstructive environments (CHAOS, negative parenting), especially in late adolescence, affect self-control in a nonshared manner, thus making twins more diverse. It is not unlikely that at the beginning of the transition period of emerging adulthood, twins are more sensitive to differential treatment by their parents if the treatment is related to negative outcomes. However, we have to keep in mind that parent–child relationships are bidirectional, and thus, children's self-control may evoke parental behavior, and/or parenting may influence children's self-control. To determine directionality in these relations, further longitudinal analyses are necessary. Additionally, we have to consider that many measures of the family environment show substantial genetic influences (Hanscombe et al., 2010; Plomin et al., 1994) because children's genetic characteristics may influence their perception of the environment. To disentangle genetic influences that are specific to self-control and family environments as well as overlapping genetic influences on them, future analyses of *TwinLife* data could consider bivariate twin models.

5.4 | Strengths and limitations

This study has several strengths. Analyses were preregistered on the *Open Science Framework* (https://osf.io/sf7q2/). We used a large representative twin family sample to investigate the development of self-control. Even though we had to use a short scale to assess self-control, construct validity was confirmed. We used latent models to control for measurement error, and we considered measurement invariance. In addition to the investigation of genetic influences on self-control, we examined potential specific environmental influences and took into account the possibility that parenting style and CHAOS could act as shared and/or nonshared environmental influences on self-control. Despite these strengths, the study also has a number of limitations.

First, the main limitation is the cross-sectional design we used for our main analyses. Although we used data from a representative large twin sample, further longitudinal analyses are necessary to determine a cause and effect relationship and to investigate the individual development of self-control. Our age span covers an important developmental period from adolescence to young adulthood. Nevertheless, previous research has shown that the development of personality traits continues into adulthood (Bleidorn et al., 2009; Kandler et al., 2015). Therefore, further research should investigate developmental changes in self-control across later adulthood. Furthermore, analyses of measurement invariance revealed significant differences between 13- and 25-year-old twins. This may indicate that it could have been advantageous to have different measures of self-control for adolescents and young adults.

Second, there are several limitations regarding the assumptions of the classical twin design (for an overview, see, Knopik et al., 2017). The classical twin design does not allow additive genetic, genetic dominance, and shared environmental effects to be investigated simultaneously. In our study, both A and D seemed to influence self-control; therefore, extended designs are necessary to identify the different genetic influences. Furthermore, the design assumes the independence of genetic and

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environmental influences, and thus, it does not account for gene-environment interactions and correlations, which can also explain differences in phenotypes.

Lastly, our study used self-reports for all variables except socioeconomic status, which was assessed by parental education, parental occupation, and family net income. It became evident that different informants can have a meaningful impact on the results. The correlations between self-control and other self-reported variables under study could be overestimated using the same informant. In contrast, the relation with socioeconomic status may be underestimated due to different informants. It would be desirable to comprise multiple informants in future studies to address this limitation.

5.5 | Conclusion

The present study combined phenotypical analyses with behavior genetic approaches to investigate genetic and specific environmental influences on self-control in adolescence and young adulthood. Although our data did not perfectly fit the personality perspective by Briley and Tucker-Drob (2017), we could identify parallels in the phenotypical and behavioral genetic development of self-control and conscientiousness. Since conscientiousness stronger relates to our applied measures of grit and self-control than to other aspects of self-regulation, these results are in line with our expectations. Furthermore, we examined the relevance of the age period from age 18 to at least age 25, called emerging adulthood (Arnett, 2000, 2014). Heritability of self-control increased during emerging adulthood, and possible underlying gene-environment correlations need to be analyzed. As expected, a structured home environment, high levels of positive parenting, and low levels of negative parenting behavior went along with children's healthy self-control development. Twins' different perceptions of CHAOS emphasize the importance of investigating typical "shared" environments from a nonshared environmental perspective and setting up interventions on an individual rather than a family level. In sum, future research on self-control should take into account that there are substantial genetic influences on self-control, and specific environments can influence self-control directly as well as indirectly through their interplay with genetic propensities.

AUTHOR CONTRIBUTIONS

All authors contributed to the study concept and design. Statistical analyses were performed by IM. Results were discussed with EH. IM drafted the manuscript and all remaining authors provided critical revisions. All authors approved the final version of the manuscript.

ACKNOWLEDGEMENT

We thank the twins and their families for participation.

FUNDING INFORMATION

The TwinLife Project is funded by the German Research Foundation (DFG) (grant number 220286500) awarded to Martin Diewald, Rainer Riemann, and Frank M. Spinath

CONFLICT OF INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS STATEMENT

The TwinLife study received ethical approval from the German Psychological Association (protocol numbers: RR 11.2009 and RR 09.2013).

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ENDNOTES

[1] *TwinLife* originally comprised four age cohorts (year of birth Cohort 1: 2009/2010; Cohort 2: 2003/2004; Cohort 3: 1997/1998; Cohort 4: 1991/1992). In the youngest cohort (Cohort 1), the parents rated their children's self-control, but because including different informants might confound the results, we decided to focus on the three older cohorts (ages 13 to 25 years).

[2] Each individual has two forms of the same gene (alleles), one transmitted from their father and one from their mother. Together, these two alleles of one individual form their genotype. For details, see Knopik et al. (2017).

[3] When modeling additive and nonadditive effects together, the classical twin design assumes their independence, although they are most likely correlated. For a detailed description of parameter indeterminacy in the classical twin design, see Keller and Coventry (2005).

[4] The chance of sharing both maternal and paternal alleles reflects the amount of shared genetic dominance variance. In the case of fraternal twins, this is 25%.

[5] Estimates refer to additive genetic variance (heritability in a narrow sense) and were calculated by Falconer's formula (Falconer, 1960) using MZ and DZ intraclass correlations from Willems et al. (2019).

[6] Internal consistency refers to the shortened five-item scale, excluding the first item.

[7] In Mplus, latent mean differences are calculated by fixing the latent mean of one group to zero and estimating the mean of the other group as a deviation from the first group.

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How to cite this article: Mueller, I. M., Spinath, F. M., Friese, M., & Hahn, E. (2023). Genetics, parenting, and family functioning—What drives the development of self-control from adolescence to adulthood?. *Journal of Personality*, 91, 332–353. https://doi.org/10.1111/jopy.12723

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