Expanding the Nomological Net of Personality Psychology

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Introduction

The issue of validity in personality psychology research has been contentious. McDonald (1999) defines validity as the degree to which a measurement instrument actually measures the psychological trait that it is intended to measure (McDonald, 1999). Under this definition, the validity of a measure depends critically on the theoretical conceptualization of the traits that it is supposed to be measuring. However, personality researchers vary in their preferred trait taxonomy.

Of the several competing frameworks of personality, the most advocated and well-researched model is the Big Five. The Big Five domains of personality were first discovered via a combination of lexical and statistical approaches. The lexical approach was first applied by Francis Galton, who perused a dictionary for entries that described a person's character (Galton, 1884) .This approach would later be articulated as the lexical hypothesis, which proposes that the most important and salient individual differences are encoded in language as single-word adjectives (Goldberg, 1990). Factor analysis has shown that a five-factor solution can account for most of the correlations among these descriptors (Digman, 1990). These five factors are: Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness to Experience/Intellect; and they are defined by the following adjectives.

- Extraversion: sociable, energetic, assertive
- Neuroticism: depressed, anxious, irritable
- Conscientiousness: organized, industrious, efficient
- Agreeableness: trusting, altruistic, sympathetic

• Openness to Experience/Intellect: intellectually curious, creative, aesthetically sensitive

The Big Five, however, is not without its detractors. Critics object to the atheoretical origin of the Big Five and the inherent social bias of language (Block, 2010). They further disapprove of factor analysis, which they claim lacks a sound procedure for picking out the optimal factor solution. There are debates over the true number of dimensions required to capture personality (Eysenck, 1991; Lee & Ashton, 2004; Tellegen, 2018), and even proponents of the Big Five disagree over the exact number of lower-order facets each factor may possess (Costa & McCrae, 2008; DeYoung et al., 2007; Soto & John, 2017).

An alternative model to the Big Five, one that is of relevance in this dissertation, is the Multidimensional Personality Questionnaire (MPQ; Tellegen & Waller, 2008). The developer of this model considers the approach underlying the Big Five to be too narrow and a priori, in that it relies excessively on the accuracy and completeness of natural language as a taxonomy of personality. At the same time, Tellegen and Waller reject a purely empirical approach, such as choosing items on the basis of their correlations with an external criterion without regard to substantive or statistical coherence. To balance rational and empirical approaches, the MPQ was developed in a hybrid manner. The MPQ consists of three broad dimensions (Positive Emotionality, Negative Emotionality, and Constraint) and eleven primary traits (Well-Being, Social Potency, Achievement, Social Closeness, Alienation, Aggression, Control, Harm Avoidance, Traditionalism, and Absorption).

Despite the differences in their development, the Big Five and MPQ models share qualitative similarities in their measures and implications. While the MPQ and Big Five scales are not exact homologs, they are analogous. Negative Emotionality corresponds to Neuroticism and Agreeableness, Positive Emotionality to Extraversion, and Constraint to Conscientiousness. Absorption, a primary trait that is not an indicator of any of the broad dimensions, is most related to Openness to Experience (Church, 1994). As might be expected from this correspondence, both models have been shown to possess validity to roughly equivalent degrees.

In the formulation of McDonald (1999), the overall validity of a trait (sometimes called "construct validity" to distinguish it from narrower forms of validity) can be supported by different types of evidence, the most elementary of which include content validity and criterion validity. Content validity broadly relates to the notion that the contents or stems of the items should on their face be indicators of the trait that the test is intended to measure (McDonald, 1999). Cronbach & Meehl (1955) defined content validity as "the test items [being] a sample of a universe in which the investigator is interested. Content validity is ordinarily to be established deductively, by defining a universe of items and sampling systematically within this universe to establish the test" (p. 282). This definition also supposes that the aptness of an item's content is not established empirically, but rather by the investigator's a priori delimitation. The lexical approach to personality seems to fit this latter definition reasonably well, since language naturally supplies the delimited universe of content. In contrast, the developer of the MPQ does not consider an obvious connection between an item's content or stem and the conceptualization of the trait to be a necessary feature of a valid item, since it may be that the researcher's current conceptualization requires advancement and refinement (Tellegen, personal communication).

Criterion validity means that the relationships that are expected to exist, based on theory or intuition, between putative measurements of a trait and external variables do in fact exist, if the trait has been properly operationalized. Traits from the Big Five and the MPQ possess criterion validity, in that the measurements of these traits have consistently been shown to predict differences in physical and mental health outcomes, academic performance, and job performance (Beck & Jackson, 2022; Caspi et al., 1997; Hudek-Knežević & Kardum, 2009; Kaplan et al., 2009; Sackett & Walmsley, 2014).

Although both the Big Five and the MPQ possess many markers of psychometric validity, many researchers have called for the further substantiation of personality taxonomies, not just through psychometric validity, but through biology. While the Big Five and the MPQ are effective as descriptive models of personality, they do not as readily translate to explanatory models of personality that put forth the biological mechanisms through which personality differences arise. We can say that the Big Five and the MPQ are genetically influenced; investigations into the heritability of personality have converged on the finding that personality is moderately heritable, with the heritability estimate for all personality traits being about 40% (Polderman et al., 2015; Vukasović & Bratko, 2015). It is less certain how heritability might fluctuate throughout the lifetime and how genetic influences may contribute the stability of personality. And the exact genomic and neurobiological basis of personality continues to undergo enquiry and scrutiny (Chen & Canli, 2022; Sanchez-Roige et al., 2018). Modern personality science is relatively nascent, and research into the underlying biology of personality highlights the need to further investigate this subject with more robust methodology.

It can be argued that the task of construct validation, for any field or subject matter, never truly ends. Validity testing and sophisticated research methods may be continually applied to a construct to see if it can be substantiated and expanded upon. Indeed, one might say that the first task of any research program in personality psychology should be to build construct validity. Even after the establishment of criterion validity or content validity, we may have to refine our initial conception of a trait by learning the fine details of its relationships with other variables, including genetic and environmental ones. “This could include concurrent measures of associated attributes, and might correspond to an informally conceived causal model, already covered as construct validity, which is the better for formalization as a path model” (McDonald, 1999, p. 450). Such refinement of validity, by looking outward rather than scrutinizing the measures of the trait, is often called expanding the “nomological net” (Cronbach & Meehl, 1955). In an iterative process, researchers should be able to generate hypotheses based on the net—as established so far—and provide evidence for those hypotheses, if the construct is valid.

The main purpose of this dissertation is to expand the nomological net of personality psychology. First, I analyze the development of personality in a longitudinal study of twins. Next, I examine how genetic confounding may overemphasize the role of the parental influence on development of self-control in an adoption study. Finally, I endeavor to validate the hierarchy of the Openness to Experience domain of the Big Five, using the biological correlate of reaction time. In sum, these studies carry out bolstering methodologies that expand the nomological net.

STUDY 1

A Longitudinal Twin Study of Normal Personality Development from Adolescence to Adulthood

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Abstract

In this longitudinal twin study, we examined the pattern and sources of personality stability and change from adolescence to adulthood. Personality was assessed by the 11 primary scales of the Multidimensional Personality Questionnaire. All scales were administered on at least four different occasions, with a maximum of seven. There were 2,346 identical and 1,329 fraternal twins ($N = 3{,}675$). Biometric Cholesky decomposition and latent growth curve modeling were performed. The results indicated that mean-level scores of traits related to Positive Affect/Extraversion generally did not change, whereas the scores of traits related to Constraint/Conscientiousness and Negative Affect/Neuroticism did change, in congruence with the maturity principle (Conscientiousness increasing with age, Neuroticism decreasing). In the biometric analyses, models included an additive genetic and nonshared environmental component and a third component being either the shared environment or dominance (a nonadditive genetic effect). Results revealed that the stability and change of several traits were influenced by additive genetic and nonshared environmental sources, with little influence from the shared environment. However, for four traits, the model with dominance effects was preferred. In these traits, both dominance and nonshared environmental sources tended to contribute about equally to stability and change. For all traits, the heritability of each trait remained relatively stable over time. These results expand upon the literature

by examining how personality develops over a 30-year period at a facet level and providing further evidence of nonadditive genetic effects.

Introduction

Personality traits are understood to be stable, yet liable to change. That is, personality traits are reflective of an individual's internal disposition and are represented by enduring patterns of thoughts, feelings, and behaviors. But they also show developmental alterations and adapt to life experiences (Specht et al., 2011). Longitudinal samples are ideal for examining how personality stabilizes or changes over time to eliminate potential effects of cohorts; however, there is a lack of literature that examines the development of personality across three or more time points over large spans of time, making it difficult to determine whether short-term trends persist throughout development. Furthermore, these studies tend to examine the large domains of personality although there is evidence to suggest that more specific traits may have unique patterns of development.

Of the several competing frameworks of personality, the most advocated and well-researched model is the Big Five. Accordingly, the literature on personality development has been mainly framed in terms of the Big Five. However, the model of relevance to this paper is the one underlying the Multidimensional Personality Questionnaire (MPQ; Tellegen & Waller, 2008). The MPQ consists of three broad dimensions (Positive Emotionality, Negative Emotionality, and Constraint) and eleven primary traits (Well-Being, Social Potency, Achievement, Social Closeness, Alienation, Aggression, Control, Harm Avoidance, Traditionalism, and Absorption). Negative Emotionality corresponds to Neuroticism and Agreeableness, Positive Emotionality to Extraversion, and Constraint to Conscientiousness. Absorption, a primary trait that is not an indicator of any of the broad dimensions, is most related to Openness to Experience/Intellect (Church, 1994).

Overview of Cross-Sectional Studies of Personality

Soto et al. (2011) examined differences across cohorts from ages 10 to 65 (late childhood to adulthood), with each age representing a single cohort. This data was collected from a sample of more than 1.2 million individuals assessed over the internet. Conscientiousness and Agreeableness showed similar differences among cohorts (although the differences in Agreeableness were less pronounced). For Conscientiousness and Agreeableness, each trait was lower in adolescents than in pre-adolescent children (approximately one-quarter of a standard deviation). Each trait was greater in adults compared to the adolescents (two-thirds of a standard deviation). For Neuroticism, there were notable differences between males and females. In females, Neuroticism was lower in the older cohorts compared to the younger cohort (an average decrease by one-third of a standard deviation). In contrast, males of different ages did not vary much on average across cohorts. Extraversion was lower in adolescents than in pre-adolescent children (one-third of a standard deviation), but adults did not differ from adolescents. For Openness to Experience, adolescents were somewhat less open than the children; young adults were relatively less open than the adolescents, and older adults were more open than young adults (approximately one-fifth of a standard deviation for all differences).

Donnellan and Lucas (2009) found mostly similar results in a cross-sectional study of British and German samples, aged 16 to 86 (n = 14,039 to 14,055 and n = 20,852 to 20,876, respectively, depending on the Big Five trait). The British sample comes from the ongoing British Household Panel Study, which began in 1991 and was initially representative of the United Kingdom. The German sample comes from the ongoing German Socio-Economic Panel Study, which began in 1984 and was also initially representative of the German population. In both samples, participants completed the 15-item version of the Big Five Inventory (John & Srivastava, 1999). Overall, older cohorts possess higher levels of Conscientiousness, Agreeableness, and Emotional Stability. The middle-aged cohort had much higher levels of those traits than the youngest cohort (approximately four-fifths of a standard deviation); and the oldest cohort had higher levels than the middle-aged cohort, though the difference between these cohorts was a small (one-fifth of a standard deviation). Unlike Soto et al. (2011), these authors reported Extraversion and Openness to Experience following dissimilar patterns of differences among cohorts. For Extraversion, older participants were more extraverted in the British sample, but less extraverted in the German sample. For Openness to Experience, older cohorts were generally less open, with the degree of the differences ranging from medium to large.

Overall, the research on cross-sectional age difference in mean Conscientiousness, Agreeableness, and Neuroticism scores is congruous. Conscientiousness appears to increase in younger and middle-aged cohorts before leveling off in older cohorts. Older adults are more conscientious than young adults, but young adults are much more conscientious than adolescents (Soto et al., 2011; Donnellan & Lucas, 2009; Allemand et al., 2007; Srivastava et al., 2003). Agreeableness also tends to increase across age cohorts, although more modestly than Conscientiousness. And Neuroticism appears to decrease. These consistent observations have been called the *maturity principle of personality development* (Caspi et al., 2005).

The literature is not consistent regarding mean-level changes in Extraversion and Openness to Experience. Various cross-sectional studies have shown that Extraversion either decreases or remains mostly stable on average with age (Soto et al., 2011; Donnellan & Lucas, 2009; Allemand et al., 2007; Srivastava et al., 2003). Even more equivocally, Openness has been shown either to increase or remain stable. In the case of Extraversion, the inconsistency has been attributed to differential age trends in the facets of Extraversion, namely "social vitality" and "social dominance" (Roberts et al., 2006). Social vitality, which is characterized by enthusiasm and gregariousness, tends to stay the same; social dominance, characterized by assertiveness and confidence, tends to increase. The differences that exist at the domain level may obfuscate the differences at the facet level.

Although cross-sectional studies can provide a starting point for understanding how personality changes over a lifetime, the extrapolation of these results to developmental insights are limited: cross-sectional studies confound age effects with cohort effects. There exists ample evidence to suggest that there are cohort effects for personality (Twenge et al., 2014). For example, using meta-analysis, Twenge (2000) examined the anxiety levels in samples of cohorts where each cohort was college aged at the time of measurement. Twenge found that levels of anxiety or Neuroticism were significantly higher in individuals born in the 1980s than those of individuals born in the 1950s. These differences in anxiety levels were correlated with factors related to low social connectedness (e.g., divorce rate, percentage of people living alone, low trust) and overall threat (e.g., crime rate, suicide rate). Twenge (2001) also found that differences in Extraversion could be attributed to cohort effects rather than true developmental changes. Longitudinal studies are not similarly bound by this limitation.

Overview of Longitudinal Studies of Personality

The results of longitudinal studies on mean-level personality development largely concur with the results of cross-sectional studies. In a meta-analysis of existing longitudinal studies from the 1960s to early 2000s, Roberts et al. (2006) found that Emotional Stability (which can be regarded roughly as reverse-coded Neuroticism), Conscientiousness, and Agreeableness increased with age. The social activity facet of Extraversion showed little change whereas the social dominance facet increased. Openness to Experience was found to increase during adolescence, but then decrease in old age.

Studies that measure personality using the MPQ also concur with Big Five studies. Though the exact magnitude of change differs by study and sample, the studies consistently show that Negative Emotionality (Neuroticism + low Agreeableness) shows mean-level decreases and that Constraint (Conscientiousness) increases (Blonigen et al., 2008; Donnellan & Lucas, 2009). Positive Emotionality is relatively stable (Blonigen et al., 2008). These personality changes are largely normative: the pattern of mean-level changes across the life span appear to be generalizable to most people at most times (Roberts et al., 2006). The mean-level changes discussed above tend to capture the average trajectories of most populations.

Individual-level changes

Though the stability/change of personality often shows consistent population-level trends, individuals do differ in the magnitude and direction of change, which may be obscured by population-level trends. And although most studies focus primarily on mean-level changes, a few studies have assessed individual-level change using the Reliable Change Index (RC; Christensen & Mendoza, 1986). The RC index quantifies the probability of observing a difference score equal to or greater than the observed difference score, assuming no actual change occurred. RC scores larger than an absolute value of 1.96 is considered reliable. The RC index is typically used in repeated-measure studies that have only two time points (Blonigen et al., 2008; Roberts et al., 2001).

Blonigen et al. (2008) applied the RC index to the MPQ, and Roberts et al. (2001) to the Big Five. Both studies examined participants first in late adolescence (~17 and ~18) and then in young adulthood (~24 and ~26). And they both found that the majority did not change over time, at least not significantly. However, the manner of change in the minority exhibiting a significant RC index was highly congruent with the pattern of mean-level change. That is, of the individuals whose level of Negative Emotionality did change, most of those individuals became less negatively emotional; of the individuals whose Constraint changed, most became more constrained.

The maturity principle states that people become more emotionally stable, agreeable, and conscientious with age—which the literature largely upholds. Furthermore, individuals who are more “mature” initially (by this definition of maturity) change the least over time. Those who are less mature change the most. This supplementary observation was articulated into the maturity- stability hypothesis (Roberts et al., 2001).

Despite the inferential advantages of these longitudinal studies over cross-sectional ones, most longitudinal studies in the literature still possess the significant drawback of only spanning a short period of time (ranging from a few years to about a decade). Those that do measure a longer period included only one or two developmental stages. To our knowledge, no longitudinal study (that is not a meta-analysis) has yet been published that covers a span as extensive as the cross-sectional studies reviewed in this paper. As a consequence of these shortcomings, these studies cannot ascertain whether mean level changes are constant with age or decelerate. The study proposed in this paper can answer these issues by examining up to seven waves of assessment across 30 years, spanning adolescence to middle age. Furthermore, this study can provide insight into the etiology of personality change by investigating contribution of genetic and environmental influences to personality development.

Biometrical analyses and longitudinal studies of twin samples

It is well-established that human behaviors, including personality, have a genetic basis or a heritable component (h^2). The genetic component of the overall variance is denoted as A, which refers specifically to variance due to additive genetic effects. “Additive” here means that statistical interactions among different sites in the genome are not included; a more general model can allow for such interactions. The other two sources of phenotypic variation are common or shared environmental effects (C) and nonshared environmental effects (E). Both genetic and shared environmental factors should lead to resemblance between individuals who are biologically related and reared together. Nonshared environmental factors have no tendency to make household members more similar. To quantify the relative contributions of these factors, a genetically sensitive study design is required. Classically, twin samples have been utilized to meet this requirement.

In a twin design, monozygotic (MZ; or identical) twins are compared to dizygotic (DZ; or fraternal) twins of the same sex. Within a pair, the twins are assumed to possess the same shared environment—parenting style, socioeconomic status, etc.—regardless of zygosity. The key difference between MZ and DZ twins is that the former share 100% of their DNA identically by descent, whereas the latter only share 50%, on average, like most other siblings. Described simply, for any heritable trait, identical twins should be more similar than fraternal twins because identical twins are twice as genetically similar as DZ twins. Differences between MZ twins must be attributed to differences in the nonshared environment.

Utilizing this methodology, researchers have investigated to extent to which personality change and stability can be attributed to the variance components. Loehlin and Martin (2001) found that the magnitudes of genetic and environmental contributions do not vastly change across the lifespan, but other research indicate the contribution of the variance components do shift (Briley & Tucker-Drob, 2014). In a longitudinal sample, Briley & Tucker-Drob found that across all domains of the Big Five, heritability substantially declined in early childhood and then steadily declined in adulthood, while environmentality (i.e., the proportion of variance attributable to all environmental factors) showed the opposite pattern. Similarly, in a cross-sectional sample using the HEXACO model of personality traits, Kandler et al. (2021) found that most traits showed differences in heritability and environmentality over time. Neither study directly estimated the presence of nonadditive genetic effects.

Nonadditive genetic effects

When genetic effects are present, they may be either additive or nonadditive. The latter is denoted by the letter D, which is derived from *dominance*. Dominance is one type of nonadditive genetic effect, in which alleles at the same site in the genome exhibit a statistical interaction. The other type of nonadditive effect is *epistasis*, which occurs when there are statistical interactions among distinct sites in the genome. In the classical twin study, it is not possible to distinguish between the types of nonadditivity, so the presence of D in a model does not solely indicate the presence of dominance, but may rather reflect epistasis or a combination of nonadditive effects. It is also not possible to jointly estimate D and C in classical twin study.

The empirical signature of nonadditive genetic variance is the correlation between MZ twins exceeding that between DZ twins by more than the factor of two based on a purely additive model—because familial resemblance depending on a precise combination of alleles will always be found in MZ twins but much less often in all other kinships. If the expression of a trait is contingent upon the exact same copies of a genetic variant being at a site or among several sites, MZ twins will display phenotypic similarity that is more than the two times greater than the similarity of other first-degree relatives (Lynch & Walsh, 1998). Strangely, personality appears to be among the few human traits where nonadditive genetic variance appears to contribute a considerable amount. In an adoption study, Plomin et al. (1998) found little resemblance between parents and offspring regardless of their adoptive status. Extended twin designs, in which data on additional family members are available, also suggest the existence of nonadditive genetic variance (Finkel & McGue, 1997; Keller et al., 2005). Although classical twin studies have reduced ability to detect nonadditivity relative to other designs, it is still worth investigating, particularly when MZ correlations seem to be greater than twice the DZ correlations.

The Present Study

Data from the Minnesota Twin and Family Study (MTFS) at the Minnesota Center for Twin and Family Research Center (MCTFR) is uniquely positioned to address the limitations of existing cross-sectional and longitudinal studies of personality development. In this sample, twins were assessed at multiple time points from adolescence to mid-adulthood. Their personality was measured using the MPQ. The purpose of this current study is to investigate longitudinal stability and change as assessed by changes in trait mean and biometric variance components with age. Furthermore, we examine the contribution of nonadditivity to personality. We focus on the primary scales of the MPQ, as investigations into the facets of personality reveal that facets within larger domains may show disparate changes or trends over time (Bleidorn et al., 2009; Soto et al., 2011). We expect that the means of the primary scales of Well-Being, Social Potency, Achievement, and Social Closeness do not change with age; Stress Reaction, Alienation, and Aggression decrease; and Control, Harm Avoidance, and Traditionalism also decrease. In terms of the biometric variance components, we expect that genetic variance will decrease with age, but environmental variance will increase for all traits.

Methods

Participants

The sample was drawn from the Minnesota Twin and Family Study (MTFS) at the Minnesota Center for Twin and Family Research Center. The MTFS is an ongoing study that began in 1989 with a sample of MZ and DZ twins from Minnesota. The participants were recruited via publicly available birth records of twins born between the years 1972 through 1984 in Minnesota. The sample was representative of Minnesota's racial composition at the time of their birth, with almost all participants being of European ancestry. In total, there are 3,675 twins who had taken a personality measurement at least once: 2,346 are monozygotic (MZ) twins and 1,329 are dizygotic (DZ) twins. In the MZ subsample, 52% are female; in the DZ subsample, 53% are female. Twins were recruited in two cohorts: one at approximately age 11 (younger cohort) and the other at age 17 (older cohort). They were followed-up every three to four years through their 40s. There have been seven waves in total, targeting these ages: 14 (younger cohort only), 17, 20, 24, 29, 35, 42. Participation rates were generally greater than 90% for waves 14 to 24, except for wave 20 which was mainly intended to assess the participants who were missed at age 17. Participation rates in waves 29 to 42 ranged from about 23% to 66%, as many participants had not yet qualified for these older assessments. The full descriptive statistics according to wave is shown in Supplemental Table 1.1. Additional information about the MTFS sample can be found in Iacono and McGue (2002).

Measure

Personality data was obtained starting at wave 14. Personality was measured using a version of the MPQ. The full MPQ contains 11 primary scales that each consist of 18-items. These scales are Well-Being (WB), Social Potency (SP), Achievement (AC), Social Closeness (SC), Stress Reaction (SR), Alienation (AL), Aggression (AG), Control (CON), Harm Avoidance (HA), Traditionalism (TR), and Absorption (AB). All scales except Absorption are subsumed in a higher-order factor. Well-Being, Social Potency, Achievement, and Social Closeness comprise Positive Effect; Stress Reaction, Alienation, and Aggression compose Negative Effect; and Control, Harm Avoidance, and

Traditionalism create Constraint. At the age-14 and age-35 waves, participants completed the Personality Booklet—Youth Abbreviated (PBYA), which includes only six of the MPQ scales (Well-Being, Stress Reaction, Alienation, Aggression, Control, and Harm Avoidance). The full 198-item MPQ was completed at subsequent assessments, except at the most recent assessment. At the age-35 and age-42 waves, participants were given the scales available in the Personality Booklet, in addition to the Traditionalism scale at age 42. Items are endorsed on a scale from *1 = Definitely True* to *4 = Definitely False*. Items are scored such that higher scores represent higher levels of the trait.

Analyses

All data was analyzed in *R* (R Core Team, 2021).

Phenotypic Analyses

The data was examined at the phenotypic level using correlations. Pearson correlations were used to calculate the rank-order stability of traits across time, using *R*'s *stats* package (R Core Team, 2021). Intraclass correlations were also conducted to compare MZ and DZ correlations, using *R*'s *ICC* package (Wolak et al., 2012).

Biometric Analyses

The data was plotted to determine the functional form of the observations; that is, the data was plotted to visually determine which kind of function could explain the relationship between the dependent personality variables and independent time variable of age. These plots typically display the individuals' raw data, or trajectories, over time as well as the predicted mean trajectory of the sample over time. The predicted mean trajectory was calculated using a generalized additive mixed model. Such models can allow the functional form to be "smoothed" by borrowing strength from nearby time points. For all traits, the trajectories appeared to be linear (see Figure 1.1). When estimating a linear random effect to higher-order terms, models with the higher-order terms showed a slightly better fit than the linear model. Despite the lack of curvature in the trajectories, higher-order terms may still be significant due to the large sample. Therefore, based on visual inspection and for ease of interpretability, we decided to proceed with a linear random effect.

A Cholesky decomposition and linear latent growth curve (LGC) analysis was fit to the data using the structural equation modeling software package OpenMx in an R environment (Neale et al., 2016). All models were fit via full information maximum likelihood to deal with missing data. This technique produces less biased, more consistent estimates, and smaller standard errors than pairwise or listwise deletion (Newman, 2003). All biometric models used the actual ages of the participant. To evaluate relative fit, the latent growth model was compared to an intercept-only model using the AIC. (Chi-square statistics were also reported, but were not used to determine model selection because of the large sample size of this study.)

Cholesky decompositions provide a general characterization of variance components at each age. It is a technique that identifies the extent to which genetic, shared environmental, and nonshared environmental sources of variance are unique to or common across ages. LGC models are a complementary technique that models change in terms of latent parameters. The repeated measures of the traits are computed as a function of time and represented by two latent factors: the intercept and slope. This model is depicted in Figure 1.2—which, for simplicity, displays only 3 waves of assessment instead of four to seven (depending on the trait) and only one individual in a twin pair.

The intercept represents the initial level of a trait and is a constant for any individual. Thus, the loadings of the assessments on the intercept have been fixed to 1. The slope is the rate of change over multiple assessments. The mean of the slope represents the average increase or decrease in trait score across time, using the actual ages of the participants.

At the phenotypic level, the variance of a measure at any given assessment can be decomposed into four sources: variability around the mean of the intercept, variability around the mean of the slope, covariance between level and slope, and systematic error. In the biometric extension of the LGC, the phenotypic variability can be further decomposed into four variance components: additive genetic (A), dominance (D), shared or common environmental (C), and nonshared or unique environmental (E). However, in a twin study where the twins were reared together, both D and C components cannot be modeled simultaneously as an ACDE model cannot be identified. Conventionally, an ACE model is considered when twice the correlation between DZ twins exceeds the correlation between MZ twins; otherwise, an ADE model is typically considered.

In the LGC, the genetic and environmental contributions to the intercept represent the variance that is stable across assessments. The genetic and environmental contributions to the slope represent systematic change. The genetic and environmental correlations between the latent factors can be estimated as well. This covariance allows an estimate of how much of the genetic and environmental influences on developmental course (slope) are shared with influences on the initial level (intercept). Each wave-specific residual is also decomposed into the ACE or ADE parameters. Measurement error is modelled as part of the E component of the residuals at each term, separately from the LGC parameters. Thus, it represents unsystematic change; parsing out the influences that do not last across assessments allows us to better understand the nature of change in each trait.

The intercept and slope were centered at the target age of the first available assessment for a given trait. The maturity principle suggests that adolescence is typically the "nadir" of personality. Thus, the intercept represented the expected value of a trait at age 14 or 17, and the slope represented the change per year averaged across all waves of assessment. To account for individual variability in age at the first wave of assessment and in the duration time between assessments, factor loadings from the slope were specified as the actual age of the individual or as definition variables. Definition variables are the observed variables used to fix the model to individual-specific data values (Mehta & Neale, 2005). Since models were fit to individual data vectors, estimating methods were based on individual likelihoods rather than the group-level summaries.

For each trait, we conducted two omnibus tests: sex differences and nested ACE/ADE models. First, to test for the effect of sex, we compared a model that allowed males and females to have differing means and covariances versus a model that constrained them to be equal. Second, we compared the full ACE model compared to the full ADE. Then the better-fitting model was compared to the reduced AE and E models. All models were compared using AIC. Results can be found in the supplement.

Results

Phenotypic Analyses

Table 1.1 displays the mean MPQ T-scores and standard deviation at each wave. The mean level of traits related to Positive Affect generally stayed similar across waves, whereas those related to Constraint increased and those to Negative Affect decreased. Lastly, Absorption decreased. Males and females largely did not differ. Traits have been grouped by higher-order factor. Broadly, all traits displayed moderate rank-order stability (see Figure 1.3).

The intraclass correlations were calculated separately for MZ and DZ twins. For all traits at all waves, the MZ correlation was greater than the DZ correlation. Sharing of environment is assumed not to differ by zygosity, so the larger MZ correlation implies that there are genetic influences. If the DZ correlation is larger than half the MZ correlation, than there is suggestive evidence that the shared environment also plays a significant role. For most traits at most times, the DZ correlation was equal to less than half the MZ correlations; the notable exceptions include Alienation, Aggression, Harm Avoidance, and Traditionalism (see Table 1.2).

The functional forms (or trajectories) of the traits are displayed in Figure 1.1. Traits related to Positive Affect appear to remain relatively stable over time, Negative Affect appears to linearly decrease over time, and Constraint appears to linearly increase over time. Absorption decreases.

Biometric Analyses

Multivariate Cholesky Models

Cholesky decomposition models were run to estimate the proportion of genetic and environmental variance at each wave. Figure 1.4 depicts the heritability estimates and 95% confidence intervals. For most traits, the heritability estimates were moderate. The exceptions were Social Closeness, Achievement, Social Potency, and Traditionalism, models which included either a dominance or shared environmental effect. The stability of heritability was formally tested by comparing the Cholesky models to models in which heritability estimates were constrained to be equal across waves. Results are provided in the supplement. For all traits, AIC indicated that the unconstrained model provided a superior fit. This suggests that the change in heritability across all waves was significant, although there is no discernible pattern (that is, an increasing or decreasing trend).

The portion of genetic and environmental sources at each wave are depicted in Figure 1.5 for females (males had similar results; see Supplementary Figure 1.1). The overall shape of the area plot represents the change in overall phenotypic variance. Phenotypic variance remained stable for most traits, notably except for Aggression and Harm Avoidance, traits which showed changes in their means over time. On average, contributions from each source appear to be relatively stable across all traits.

Latent Growth Curve Models

The results of the omnibus tests are shown in Supplementary Table 1.2. To test for sex differences, models in which sex differences were allowed were compared to models in which parameters were constrained to be equal across sex. To ascertain the best-fitting model, A, C, and/or D parameters were constrained to 0 and compared to the full ACE or ADE model. Decisions were made based on AIC. For all traits, the sex-differences model fit the best. For Well-Being, Stress Reaction, Harm Avoidance, and Absorption, the AE model improved fit over the ACE or ADE model. For four traits (Social Potency, Achievement, Social Closeness, and Control), the ADE model was best. And for three traits (Alienation, Aggression, and Traditionalism), ACE was best. The final model parameter estimates for each trait can be viewed in Table 1.3.

In general, in the AE models, the additive and nonshared environmental factors equally influenced the intercept, while the latter predominantly contributed to the slope. In ADE models, influences on both stability and change were mainly attributable to genetic and environmental factors. The presence of the genetic factor was mainly due to dominance effects, with little to no influence from additive genetics. While the MZ-DZ correlations did suggest the existence of dominance effects, the absence of additive effects was unexpected. Turning to the ACE models, although the AIC indicated that the inclusion of shared environmental effects for Alienation and Aggression, the C estimates for the intercept and slope were negligible. For Traditionalism, the shared environmental variances were small, but significant. In all ACE models on average, the additive effects on the intercept were prominent, while nonshared environmental factors were small. The reverse was true for the slope.

Discussion

This study provides an investigation into the etiology of personality over an extended developmental period. We aimed to further uncover the pattern and sources of personality stability and change from adolescence to mid-adulthood by using a Cholesky and LGC with longitudinal twin data. Phenotypic analyses showed that mean-level changes generally followed the maturity principle, with scales related to Negative Affect decreasing and those related to Constraint increasing. The twin correlations also suggested the presence of nonadditive genetic effects for certain scales. Biometric analyses revealed that for all scales there were nonshared environmental factors that influenced both stability and change, with a more predominant effect on the latter. All scales were influenced by the nonshared environment; traits differed by which other variance component(s) contributed to the scale. According to the best-fitting models, four of the traits were also influenced by additive genetic factors, another third by additive genetic factors and dominance deviations, and the last third by additive genetics and the shared environment.

Etiology of Stability and Change

This study replicates prior findings of substantial personality stability in adulthood. This study extends prior findings by expanding the time over which personality development is examined. For most traits, the genetic influences present at earlier timepoints were still present at subsequent timepoints, as A, C, D, or E effects were generally moderately or strongly correlated across waves of measurement (see Supplementary Figures 1.2 and 1.3). At the same time, results indicated that the nonshared environment plays a role in personality stability as the E variance of the intercept and the E correlations across waves were moderate.

Consistent with Bleidorn et al. (2009), the stability of almost all scales were influenced by genetic and nonshared environmental factors; and the change in most scales was mostly driven by the nonshared environment, although a few scales had a small, but significant contribution from genetic factors. The results here and in Bleidorn et al. are better able to detect genetic effects on change, as LGCs allows us to parse random error from variance due to “true” change. These results also align with Bleidorn et al. in that scales that comprise a higher-order factor did not develop in the same patterns, but rather followed heterogeneous developmental paths. For example, in this study, the scales that compose the Constraint higher-order factor (Control, Harm Avoidance, and Traditionalism) were not found to have the exact same sources or patterns of etiology. This finding falls in line with literature (Briley & Tucker-Drob, 2012) recommending that focus be turned from higher-order domains to lower-order facets, as lower-order facets within a personality domain may be composed of distinct etiologies that underlie complex psychological structures. However, it is also possible that the difference in the variance compositions of scales within the higher-order factors may be the result of noise and a lack of power.

Etiology of Variance

Using the Cholesky models, we also examined the overall variance at each wave of measurement as well as how the contribution of each source of variance changed over time. For most traits, the overall phenotypic variance did not vary across waves. The notable exceptions were Aggression and Harm Avoidance. Both traits decreased in variance, with the variance in Aggression having the most pronounced reduction. In terms of etiology, the sources of variance also did not change over time. Generally, each source tended to contribute an equal proportion to the phenotypic variance across each wave for all traits. Figure 1.4 displays the estimate of heritability, which remained between 40% to 60% across all traits. When tested if the change in heritability was significant, the change was significant, although no clear pattern of change emerged. In comparison, Briley & Tucker-Drob (2014) who found that genetic variance substantially decreased beginning in early adulthood, while environmental variance increased in longitudinal sample of sibling pairs. Using the HEXACO model of personality in a cross-sectional sample, Kandler et al. (2021) found heritability slightly increased into early-mid adulthood for Extraversion, Agreeableness, and Openness, but decreased in mid-late adulthood for most traits. And for most traits, the nonshared environment played an increasingly important role.

Nonadditive Genetic Effects

Turning to the ADE models, this study found evidence for nonadditivity as evidenced by the relatively larger MZ correlations and the four scales (Social Potency, Achievement, Social Closeness, and Control) for which the ADE model was preferred. The intercept and slope estimates showed moderate to large dominance genetic effects, but little to no additive effects. However, it is not biologically plausible for dominance effects to exist without additive effects. This finding is likely attributable to the fact that A and D are subject to a large negative sampling correlation (Keller and Conventry, 2005). The precision of A and D estimates when both are included in a model is low.

The detection of nonadditivity in the MPQ has been observed previously. Matteson et al. (2013) found evidence of a significant influence of the D component, but no significant influence of A in a twin-adoption design, which allowed them to model C and D simultaneously. In the full ACDE model, significant D effects were observed in Social Potency, Achievement, Social Closeness, Control, Harm Avoidance and Absorption. Interestingly, in Matteson et al.'s study, Control was the one scale for which all genetic influence could be attributed solely to nonadditive effects. Similarly in this study, A was estimated to be a nonzero (although occasionally nonsignificant) value for all traits except Control, for which A was estimated to be zero. Other studies of the MPQ have varied in which traits are found to have nonadditive effects. In a twin-family design, Finkel and McGue (1997) found evidence for nonadditive genetic influences in every scale except Traditionalism and Absorption. The exact proportion of genetic variance due to nonadditive effects also differed by scale. Both Tellegen et al. (1988) and Waller and Shaver (1994) found evidence for nonadditivity in Social Potency and Control, while the latter detected nonadditivity in Social Closeness, Stress Reaction, and Harm Avoidance as well.

Research using other personality scales has also suggested nonadditive genetic influences. In a study of the Big Five, Jang et al. (1996) observed nonadditive genetic effects on Openness, Agreeableness, and Neuroticism at the domain level and various facets of Openness as well. Johnson and Krueger (2004) found that some models including the effect of D significantly improved fit in Openness and Agreeableness. In contrast, South et al. (2018) found that no ADE model of a trait fit better than an AE model. A common limitation among these studies was the use of a twin design. Nevertheless, parent-offspring correlations tend to be small. (Loehlin, 2009) compiled correlations from 859 studies on some personality trait between parents and offspring. For biological offspring reared by their biological parents, the average correlation was .13; for adopted offspring, it was .04; and for biological offspring adopted away, it was .13. Correlations between biological siblings are often small as well (Finkel & McGue, 1997).

Studies of genetic variance components point to additivity as the predominant form of genetic variance across many behavioral and physiological traits (Polderman et al., 2015). Even though nonadditivity plays an important role in biological functioning, it may not contribute much to statistical variability in populations. Hill et al. (2008) proposed that this phenomenon may be explained by derived alleles tending to be at low frequencies. The typical trajectory of a derived allele is to start at a low frequency upon its appearance by mutation, bounce around at low frequencies for a short time, and then disappear as a result of chance fluctuations. Natural selection will tend to further shorten the sojourn time of a derived allele, since most mutations with phenotypic effects are at least slightly deleterious. What this means is that multiple-site genotypes composed of many derived alleles are relatively rare, leading to a smaller "effective" number of genotypes in the population. This principle can be illustrated in the simple case of a single site; if the derived allele is at low frequency, then only two genotypes are relatively common (homozygous ancestral, heterozygous). A straight line can always be fit to two data points. But if this is the explanation of why the genetic variance of a typical trait is mostly additive, it raises the question of why human personality seems to show an exceptional degree of nonadditive genetic variance. We do not have an explanation and suggest that future biometrical and genomic research on personality should investigate this issue.

Shared Environment

A striking finding in behavior genetics is that the resemblance among biological family members is primarily due to genetic factors, with little to no influence from the shared environment (Krueger et al., 2008; Loehlin, 1976; Plomin & Daniels, 1987; Polderman et al., 2015). This finding suggests that, in the case of personality, parenting does not make offspring more similar to one another beyond their shared genetic background. It is possible that parenting, rather than acting as an environmental agent that increases offspring similarity, causes offspring to behave less similarly. In this study, the ACE model was found to best fit Aggression, Alienation, and Traditionalism. However, only Traditionalism had a significant C estimate. In comparison, Matteson et al. (2013) estimated significant C components in Absorption, Alienation, Harm Avoidance, and Traditionalism in the full ACDE models. The presence of C in these scales may be explained by the social quality of these traits, as these behaviors are expressed in an interactive and communicative nature (Tellegen et al., 1988).

Traditionalism in particular is not surprising to have a C effect as it is conceptually related to religiosity, which has been previously shown to be influenced by the shared environment (Beer et al., 1998; Willoughby et al., 2021). Age is a likely moderator of heritable influences on religiosity, as heritability estimates are low in younger samples and moderate in adults (Koenig et al., 2005). This difference in heritability by age suggests the importance of internal disposition emerges over time while the influence of external forces decrease.

Limitations

This study is limited by the use of self-report data, and the response and rater biases that may occur as a result. One particular type of rater bias that has been proposed to occur in self-report data on personality is a contrast effect. When rating their personalities, family members may compare themselves to one another rather than the population mean. Contrast effects result in the underestimation of correlations, which may obscure the effect of the shared environment. To overcome this bias, Riemann et al. (1997) conducted biometric analyses on Big Five data from peer reports. An AE model appropriately fit most domains of the Big Five, but not all. Agreeableness was equally fit by a CE model, and Neuroticism was better fit by a DE model. In an observational study, judges rated the personality of twins, whom they never met, based on videotaped behaviors (Borkenau et al., 2001). The AE model provided the superior fit to the ACE model for most traits; however, the authors noted that the study lacked the power (*N* = 300) to establish the presence of a small to moderate shared environmental influence. Dominance effects were not estimated.

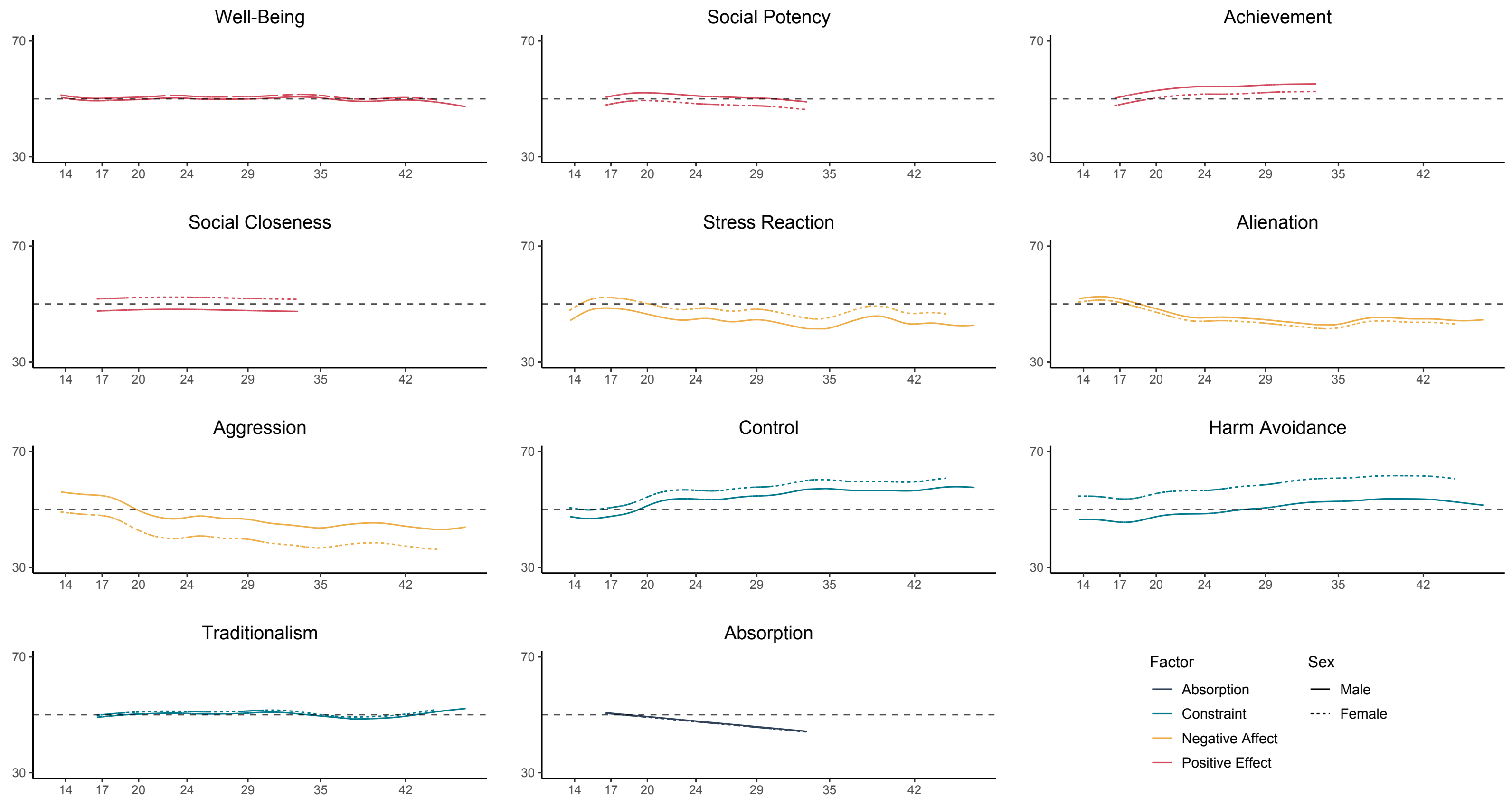
Another limitation of this paper includes the shortcomings of using the classical twin design. The twin design relies on three key assumptions: that any sharing of environmental factors does not depend on zygosity, that there is no assortative mating, and that *either* there is no nonadditive genetic variance *or* there is no influence of shared environment. While the share environment can be roughly estimated with the classical twin study without using the extended family, the shared environment cannot be precisely estimated with twin data alone. However, the results here show convergence with other studies that have extended the twin design. Shared environmental effects tend to be minimal, and the magnitude of nonadditivity is noteworthy.

Conclusion

This study is an important next step in understanding the etiology of personality as it develops in a longitudinal sample. The results here suggest that personality stability during both adolescence and adulthood results from a combination of genetic and nonshared environmental influence, and notably, a considerable amount of that influence can be attributed to nonadditive genetic effects. Personality change, in contrast, appears to primarily be brought on by new life events as individuals age. There is continually mounting evidence that the shared environment has little to no effect on personality stability or change, while nonadditive genetic effects do have an appreciable influence.

Figure 1.1

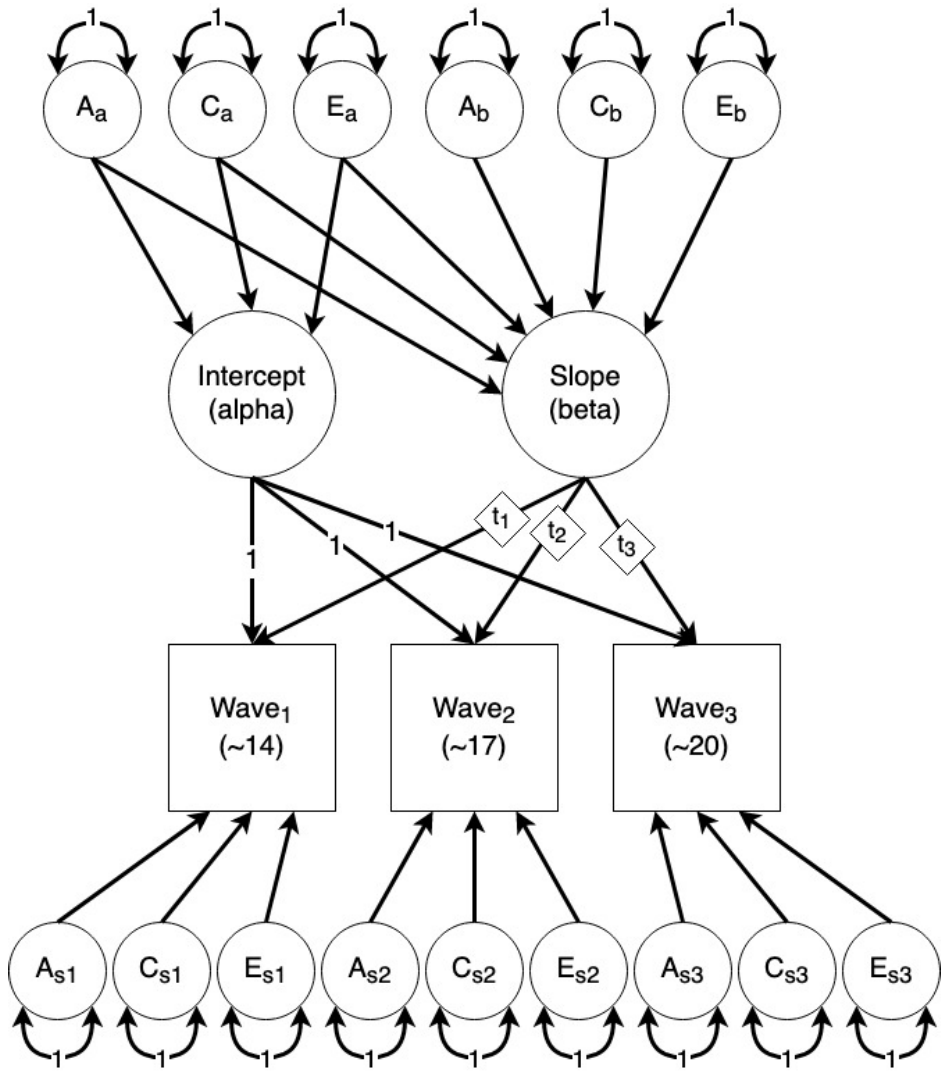
General Additive Mixed Models of Predicted Trajectory of Personality



Note. Generalized additive mixed models showing predicted trajectory of personality over time, accounting for family structure. Scores have been transformed to T-scores, centered at age 17, in males and females separately. The y-axis has been truncated to begin at 30 and end at 70 for visual clarity. Color represents high order factor. Line type represents sex; the center black dashed line represents 50.

Figure 1.2

Example Linear Latent Growth Curve Model



Note. Path diagram of a linear latent growth curve with individually varying time scores and ACE decomposition. Boxes represent measured variables. Circles represent latent and ACE factors. Diamonds represent individual-specific measurement times; participants' actual ages were used. Straight arrows represent regression paths. Curved arrows represent variance.

Table 1.1

Mean and Standard Deviation of Each Trait by Wave and Sex

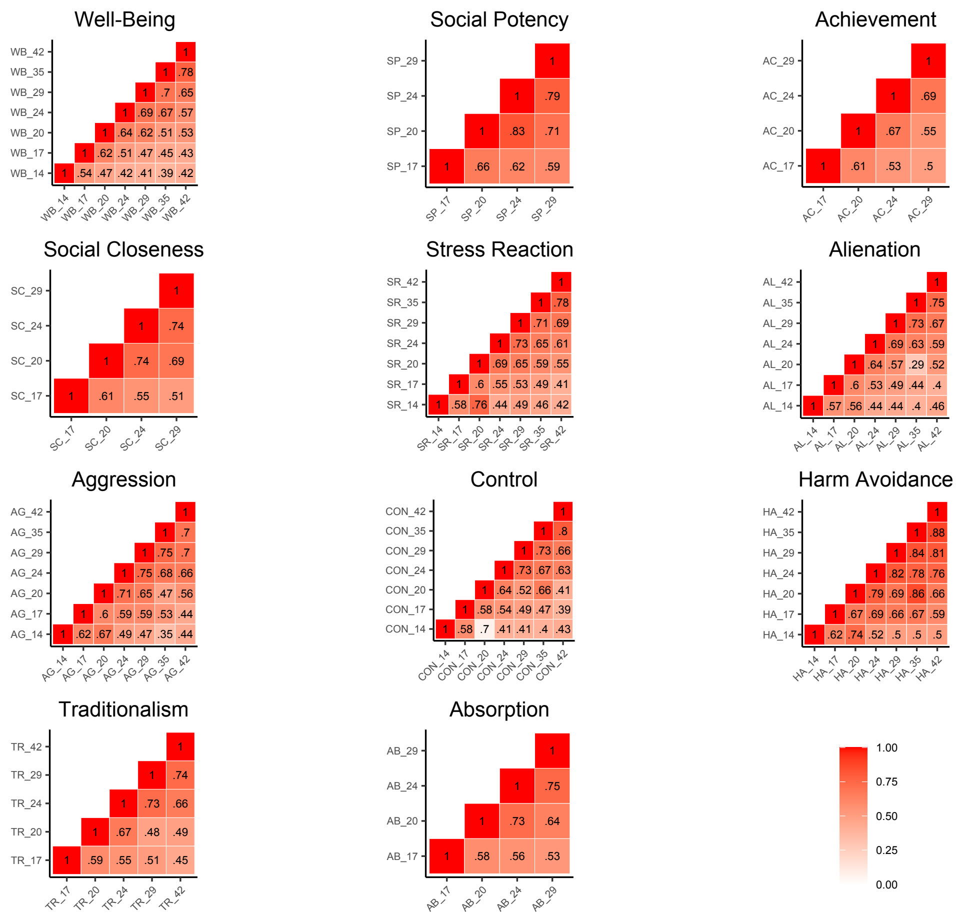
Scale	Wave													
	14		17		20		24		29		35		42	
	N	*M* (*SD*)	*N*	*M* (*SD*)	*N*	*M* (*SD*)	*N*	*M* (*SD*)	*N*	*M* (*SD*)	*N*	*M* (*SD*)	*N*	*M* (*SD*)
Well-Being														
Male	429	49.87 (10.25)	1538	50.00 (10.00)	151	50.55 (10.90)	1364	50.65 (10.53)	1138	50.37 (10.26)	377	50.16 (11.31)	454	48.81 (10.76)
Female	1135	50.52 (10.34)	1728	50.00 (10.00)	614	50.19 (9.79)	1686	50.59 (9.53)	1289	50.48 (9.65)	481	51.84 (9.08)	612	49.65 (9.22)
Social Potency														
Male	-	-	1542	50.00 (10.00)	151	51.28 (11.13)	1029	51.11 (10.76)	1139	50.58 (11.16)	-	-	-	-
Female	-	-	1729	50.00 (10.00)	32	53.42 (8.72)	1256	48.30 (10.08)	1290	47.63 (10.28)	-	-	-	-
Achievement														
Male	-	-	1537	50.00 (10.00)	151	51.92 (10.11)	1026	53.87 (9.61)	1139	54.49 (9.72)	-	-	-	-
Female	-	-	1729	50.00 (10.00)	32	52.38 (8.17)	1252	51.17 (9.16)	1290	52.82 (9.50)	-	-	-	-
Social Closeness														
Male	-	-	1544	50.00 (10.00)	151	49.43 (11.00)	1031	49.90 (10.62)	1142	49.30 (10.65)	-	-	-	-
Female	-	-	1735	50.00 (10.00)	32	56.21 (7.78)	1257	51.01 (9.31)	1291	50.70 (9.56)	-	-	-	-
Stress Reaction														
Male	428	49.02 (9.55)	1540	50.00 (10.00)	151	50.38 (9.34)	1364	46.79 (10.37)	1140	46.16 (10.28)	375	42.60 (10.55)	454	47.66 (11.28)
Female	1135	48.13 (10.20)	1731	50.00 (10.00)	617	48.52 (10.04)	1686	46.44 (10.11)	1289	46.97 (10.00)	481	43.28 (9.95)	612	46.98 (10.42)

Alienation														
Male	427	52.81	1541	50.00	151	48.67	1336	44.49	1139	43.47	377	41.32	454	44.67
		(10.34)		(10.00)		(9.24)		(9.94)		(9.75)		(9.77)		(10.10)
Female	1134	50.92	1731	50.00	617	46.96	1688	44.57	1290	43.92	481	41.74	613	44.67
		(10.27)		(10.00)		(8.89)		(9.00)		(9.13)		(8.76)		(8.97)
Aggression														
Male	430	51.87	1540	50.00	151	45.21	1366	42.83	1139	41.51	377	37.84	454	39.40
		(10.10)		(10.00)		(9.10)		(9.06)		(8.53)		(7.77)		(7.60)
Female	1134	51.25	1732	50.00	617	45.28	1688	43.47	1289	43.10	481	39.82	612	41.89
		(10.38)		(10.00)		(8.05)		(7.44)		(7.06)		(6.07)		(5.95)
Control														
Male	429	47.99	1541	50.00	151	52.31	1364	53.97	1139	55.59	377	58.58	454	58.47
		(10.68)		(10.00)		(10.49)		(10.53)		(10.22)		(10.68)		(9.96)
Female	1130	49.32	1728	50.00	615	55.10	1690	56.06	1291	56.77	481	59.47	613	58.19
		(10.17)		(10.00)		(9.44)		(9.59)		(9.43)		(10.08)		(9.34)
Harm Avoidance														
Male	421	53.17	1540	50.00	151	52.20	1365	52.04	1139	53.57	374	56.01	455	58.04
		(10.39)		(10.00)		(10.33)		(10.83)		(10.87)		(11.06)		(10.54)
Female	1125	50.52	1733	50.00	617	53.36	1689	54.18	1288	56.30	480	57.18	613	58.28
		(9.99)		(10.00)		(9.35)		(9.51)		(9.35)		(9.14)		(8.23)
Traditionalism														
Male	-	-	1527	50.00	151	52.93	1018	51.92	1132	52.59	-	-	451	51.91
				(10.00)		(11.98)		(11.17)		(10.60)				(10.62)
Female	-	-	1716	50.00	32	52.71	1240	50.78	1278	50.80	-	-	611	49.45
				(10.00)		(7.07)		(9.58)		(9.82)				(10.69)
Absorption														
Male	-	-	1539	50.00	151	50.59	1025	48.38	1140	46.51	-	-	-	-
				(10.00)		(10.29)		(10.23)		(10.67)				
Female	-	-	1729	50.00	32	45.90	1251	46.74	1288	45.18	-	-	-	-
				(10.00)		(10.04)		(9.59)		(9.66)				

Note. Variables were transformed to a T-score metric, in males and females separately, using the mean and standard deviation of the age-17 wave.

Figure 1.3

Phenotypic Correlations of Traits Across Waves



Note. Traits have been grouped by higher-order factor. Saturation relates to the magnitude of the value. WB = Well-Being, SP = Social Potency, AC = Achievement, SC = Social Closeness, SR = Stress Reaction, AL = Alienation, AG = Aggression, CON = Control, HA = Harm Avoidance, TR = Traditionalism, AB = Absorption.

Table 1.2

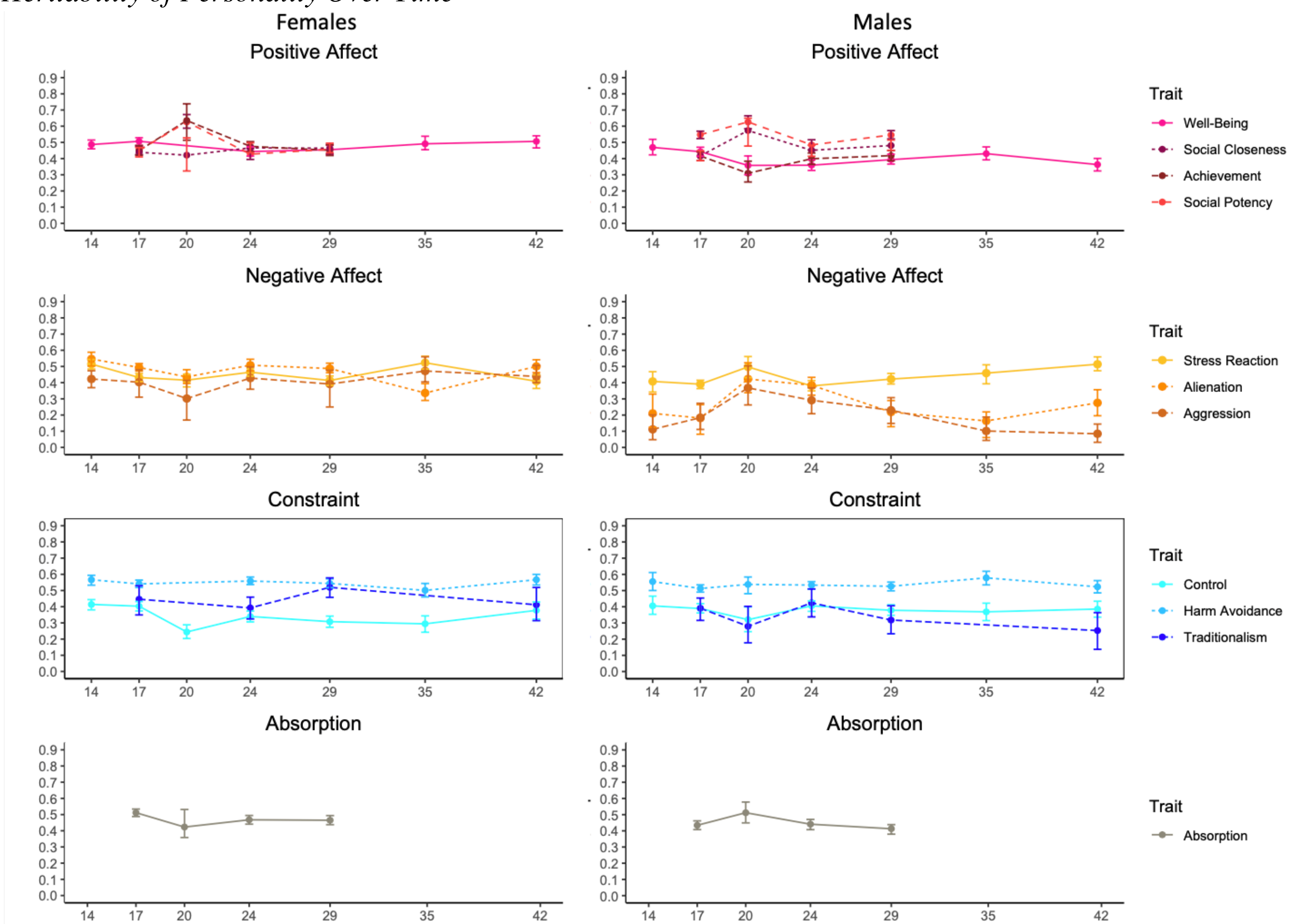
Intraclass Correlations between MZ and DZ twins by Trait and Wave

Scale	Wave													
	14		17		20		24		29		35		42	
	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ
WB	.49	.25	.50	.43	.16	.44	.43	.16	.44	.21	.46	.19	.47	.11
	(465)	(301)	(1034)	(585)	(237)	(121)	(897)	(514)	(746)	(408)	(243)	(149)	(295)	(149)
SP	-	-	.49	.12	.61	.49	.45	.23	.51	.21	-	-	-	-
			(1038)	(586)	(53)	(29)	(685)	(372)	(748)	(407)				
AC	-	-	.44	.13	.27	.06	.45	.14	.45	.14	-	-	-	-
			(1034)	(585)	(53)	(29)	(679)	(371)	(747)	(408)				
SC	-	-	.44	.11	.64	.37	.47	.20	.50	.14	-	-	-	-
			(1042)	(590)	(53)	(29)	(687)	(373)	(749)	(409)				
SR	.50	.23	.44	.21	.42	.22	.45	.23	.41	.22	.51	.25	.43	.10
	(466)	(299)	(1036)	(588)	(239)	(122)	(899)	(513)	(747)	(409)	(242)	(148)	(295)	(149)
AL	.57	.32	.50	.28	.41	.25	.48	.29	.46	.21	.45	.16	.48	.23
	(462)	(301)	(1038)	(587)	(239)	(122)	(900)	(515)	(748)	(408)	(243)	(149)	(295)	(150)
AG	.53	.38	.57	.30	.53	.29	.60	.37	.55	.36	.56	.27	.49	.28
	(464)	(302)	(1038)	(587)	(239)	(122)	(900)	(516)	(746)	(409)	(243)	(149)	(295)	(149)
CON	.40	.20	.39	.05	.21	.22	.38	.08	.32	.10	.33	.07	.32	.15
	(463)	(299)	(1036)	(586)	(238)	(121)	(900)	(515)	(747)	(409)	(243)	(149)	(295)	(150)
HA	.60	.16	.58	.30	.54	.23	.63	.41	.63	.39	.61	.37	.57	.34
	(452)	(296)	(1037)	(588)	(239)	(122)	(902)	(515)	(746)	(407)	(240)	(148)	(296)	(150)
TR	-	-	.57	.36	.62	.55	.39	.39	.38	.38	-	-	.60	.44
			(1023)	(574)	(53)	(29)	(732)	(669)	(404)	(734)			(295)	(147)
AB	-	-	.48	.23	.47	.24	.46	.23	.44	.19	-	-	-	-
			(1036)	(583)	(53)	(29)	(678)	(371)	(746)	(408)				

Note. WB = Well-Being, SP = Social Potency, AC = Achievement, SC = Social Closeness, SR = Stress Reaction, AL = Alienation, AG = Aggression, CON = Control, HA = Harm Avoidance, TR = Traditionalism, AB = Absorption. Parentheses show the sample size in pairs.

Figure 1.4

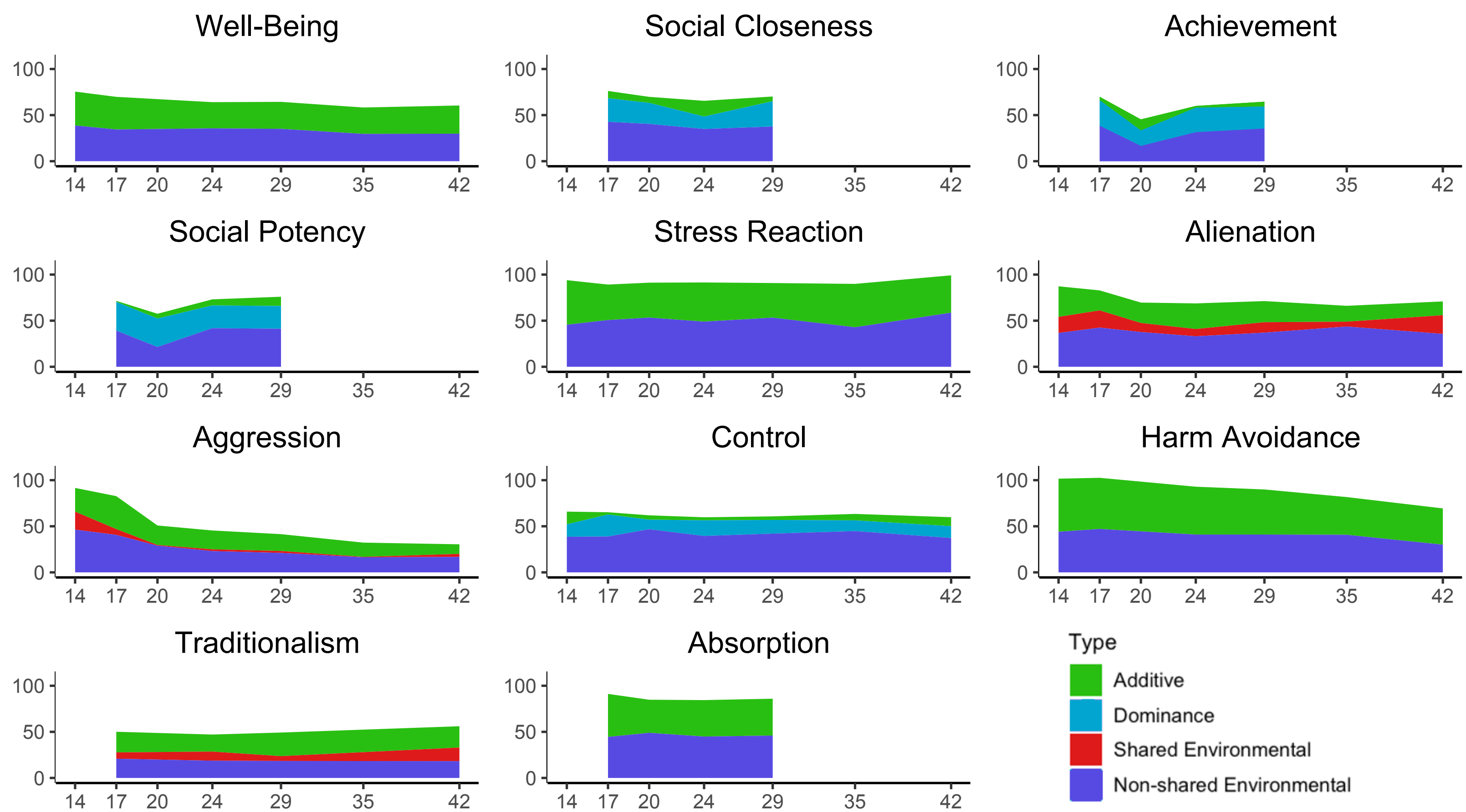
Heritability of Personality Over Time



Note. The x-axis is the wave. The y-axis is the estimated heritability, in the broad sense if a dominance component was estimated (e.g., for Social Closeness, Achievement, Social Potency, and Control). Bars indicate the 95% confidence interval.

Figure 1.5

Stacked Unstandardized Variance Components in Females



Note. Stacked unstandardized variance components of additive genetic, dominance, shared and nonshared environmental effects across waves based on the best fitting models. Results for males can be found in Supplementary Figure 1.1.

Table 1. 3

Decomposition estimates of the intercept and slope based on the best fitting models.

Scale	I				S			
	A	C	D	E	A	C	D	E
Well-Being								
Male	.55	-	-	.45	.20	-	-	.80
	[.41, .59]			[.41, .50]	[.08, .33]			[.67, .92]
Female	.66	-	-	.34	.41	-	-	.59
	[.62, .69]			[.31, .38]	[.32, .49]			[.51, .68]
Social								
Closeness	.07	-	.53	.40	.00	-	.42	.58
Male	[.00, .29]		[.32, .66]	[.33, .47]	[.00, .02]		[.31, .55]	[.46, .69]
	.25	-	.31	.44	.01	-	.27	.72
Female	[.04, .43]		[.11, .54]	[.36, .51]	[.00, .04]		[.10, .48]	[.52, .90]
Achievement								
Male	.01	-	.40	.60	.25	-	.00	.75
	[.00, .01]		[.30, .50]	[.53, .66]	[.14, .39]		[.00, .00]	[.65, .87]
Female	.03	-	.69	.29	.80	-	.00	.20
	[.00, .08]		[.62, .75]	[.23, .35]	[.56, .95]		[.00, .00]	[.04, .46]
Social Potency								
Male	.44	-	.23	.33	.00	-	.45	.55
	[.21, .64]		[.02, .45]	[.35, .55]	[.00, .01]		[.35, .55]	[.45, .66]
Female	.25	-	.31	.44	.23	-	.00	.77
	[.00, .51]		[.47, .61]	[.40, .86]	[.14, .34]		[.00, .01]	[.66, .86]

Stress Reaction								
Male	.53	-	-	.47	.49	-	-	.51
	[.48, .59]			[.39, .63]	[.37, .61]			[.39, .63]
Female	.61	-	-	.49	.29	-	-	.71
	[.58, .65]			[.35, 42]	[.19, .38]			[.62, .81]
Alienation								
Male	.55	.00	-	.45	.04	.00	-	.96
	[.51, .60]	[.00, .08]		[.41, .49]	[.02, .06]	[.00, .00]		[.94, .98]
Female	.52	.16	-	.32	.17	.00	-	.83
	[.41, .63]	[.07, .26]		[.28, .35]	[.05, .35]	[.00, .00]		[.71, .94]
Aggression								
Male	.65	.00		.35	.02	.00	-	.98
	[.53, .78]	[.00, .25]		[.24, .46]	[.00, .12]	[.00, .42]		[.88, 1.00]
Female	.66	.00		.33	.58	.00	-	.42
	[.58, .79]	[.00, .08]		[.23, .42]	[.38, .92]	[.00, .12]		[.14, .62]
Control								
Male	.00	-	.57	.43	.00	-	.26	.74
	[.00, .12]		[.50, .63]	[.39, .48]	[.00, .04]		[.14, 38]	[.63, .86]
Female	.00	-	.46	.54	.00	-	.20	.80
	[.00, .01]		[.41, .50]	[.50, .59]	[.00, .22]		[.10, .30]	[.71, .88]
Harm								
Avoidance	.72	-	-	.28	.46	-	-	.54
Male	[.69, .76]			[.24, .31]	[.37, .55]			[.45, .63]
	.68	-	-	.32	.27	-	-	.73
Female	[.66, .71]				[.18, .35]			[.65, .82]

Traditionalism								
Male	.61	.20	-	.20	.59	.08	-	.33
	[.51, .71]	[.11, .27]		[.16, .23]	[.35, .76]	[.00, .34]		[.22, .44]
Female	.56	.20	-	.23	.06	.28	-	.66
	[.43, .68]	[.09, .33]		[.19, .27]	[.00, .20]	[.14, .51]		[.55, .80]
Absorption								
Male	.61	-	-	.39	.09	-	-	.91
	[.54, .66]			[.34, .46]	[.02, .23]			[.77, .98]
Female	.62	-	-	.38	.28	-	-	.72
	[.56, .68]			[.32, .44]	[.17, .40]			[.60, .83]

Note. The bracketed values are the 95% confidence intervals.

STUDY 2

Parenting and Self-Control: A Longitudinal Study of Adoptees

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Abstract

Using a sample of adoptive and nonadoptive children from the Sibling Interaction and Behavior Study from the Minnesota Center for Twin and Family Research Center, this study analyzed the relationship between parenting—as measured by the Parental Environmental Questionnaire—and self-control, as well as parenting and aggression, across two waves of measurement in adolescence. Employing phenotypic and behavioral-genetic methods, we converged on two major findings. First, parenting was generally significantly associated with self-control within waves at the phenotypic level, but there was little evidence to suggest that parenting had a concurrent or longitudinal influence on self-control. Second, self-control appeared to be moderately heritable in early adolescence and not heritable at all in late adolescence; over this span the nonshared environment seemed to grow in relevance. This study demonstrates the importance of controlling for genetic confounding when investigating the nature of parent-child relationships.

Keywords: self-control, aggression, parenting, behavior genetics, developmental

Introduction

The ability to regulate impulses and adopt an extended time horizon when making decisions arises from a suite of cognitive functions, many of which are shared across human and non-human primates, as well as various other animal species (MacLean et al., 2014). Among the cognitive functions hypothesized in decision making, the relatively generic term "self-control" is often used to reference a broad trait which captures variation across self-regulation, effortful control, impulsivity, and risk-taking (McCrae & Löckenhoff, 2010; Nigg, 2017). Each of these narrower terms may depart slightly in the specifics of their operationalization, but all of them refer to the ability (or inability) to govern behaviors (Bridgett et al., 2015; Nigg, 2017). Understood in this way, self-control has emerged across the behavioral sciences as a robust correlate of key outcomes, including economic success, health, violence, and aggression (Pratt & Cullen, 2020). What seems beyond debate is that self-control represents a component of cognitive and psychological functioning which is essential for navigating numerous aspects of social life (de Ridder et al., 2012).

In contrast, the etiology of self-control remains comparatively less well understood. Since it is evident that individuals in the population vary considerably in their ability to constrain and control impulsive outcomes—possibly owing in part to variation in underlying functions stemming from cortical structures (MacLean et al., 2014)—parsing the genetic and environmental sources of variation in self-control, not surprisingly, has been a central interest of researchers in the developmental sciences. As work on the topic has accumulated, a common theme has emerged: variation in self-control is partly heritable, with remaining portions of variation attributable to the unique (or nonshared) environmental experiences of individuals (Willems et al., 2019). In this regard, self-control reflects the prevailing "laws" of complex quantitative outcomes (see Chabris et al., 2013; Polderman et al., 2015).

A useful, if not paradoxical, property of genetically informed analyses is that they represent among the clearest evidence available that the *environment* plays an important role in creating variation in self-control, while remaining opaque on which precise environmental factors matter the most. Nevertheless, there has been a longstanding interest in one particular component of human environments for decades: parents (Carter, 2001; Gibbs et al., 1998; Perrone et al., 2004). Indeed, much of the early and current research on self-control centers around a common assumption that a child's interactions with their parents exert some influence on their ability to modulate impulses. Support is not lacking on this topic, as various parenting factors correlate with self-control. Meta-analyses, over a decade ago and again more recently, have suggested that the interactional styles and management practices of parents are associated with the development of offspring self-control, particularly during early and middle childhood (Davis et al., 2017; Karreman et al., 2006).

At a granular level, several specific attributes of parenting have been of central focus. Early infant-caregiver attachment and reciprocal patterns of communication, for instance, have garnered close scrutiny (Kopp, 1982). The ways in which parents monitor and attempt to regulate their child's behaviors are also considered important, as evidenced by arguments that these "external" sources of regulation become progressively internalized (see also Gottfredson & Hirschi, 1990). With the passage of time, developmental researchers increasingly viewed parent-child relationships as more complex, and not as much unidirectional (influence running parent to child), but directional. It should not be surprising, then, that scholars have steadily eschewed more simplistic explanations in favor of bidirectional models which assume that influences run in both directions between child and parent (Dunn, 1997; Wills & Yaeger, 2003). These more nuanced models of parenting place considerable emphasis on the parents' response to children in conjunction with a child's influence on the parents' behaviors (Kuczynski, 2003). Nonetheless, parenting styles have remained a focus in the developmental sciences, particularly when children are young. The extent to which associations between parenting and childhood self-control persist into adolescence and early adulthood—especially with models accounting for child-driven influences—is a topic that has been understudied by comparison, though a reasonable amount of work has been done.

Of the work on self-control devoted to adolescence and early adulthood, results have been more equivocal. A recent meta-analysis of cross-sectional and longitudinal research by Li et al. (2019) examined prior work carried out on adolescents aged 10 to 22 years old. Parenting measures were grouped into three broad categories: positive parenting, negative parenting, and parent-child relationships. Positive parenting was defined as active and direct control of the child (such as supervision and authoritative control); negative parenting as negative control (coercive punishment and authoritarian parenting) and hostility (which included harsh parenting, inconsistent discipline, coercive punishment, authoritarian parenting, and permissive parenting); and parent-child relationship as the quality of the emotional bonds between parent and child. In keeping with prior work, the findings suggested that parenting styles may have a direct and causal effect on self-control, both cross-sectionally and longitudinally. The authors were willing to interpret their findings as evidence of a reciprocal causal relationship between parenting and self-control: "The current study suggests that parenting significantly contributes to self-control in adolescents aged 10 to 22 years. It also suggests that adolescent self-control shows a significant lagged effect on subsequent parenting" (p. 992). Positive parenting in particular appeared to foster the development of self-control, while negative parenting seemed to discourage it.

Parents, Self-Control, and the Difficulty of Causal Inference

Given the current state of the literature, a defensible conclusion seems to be that self-control *correlates* with various parenting styles. The primary difficulty arises when one attempts to make stronger assertions concerning *causality*. Not unlike many other topics in the developmental sciences, clarity concerning causal inference involves confronting a particular methodological concern (Barnes et al., 2014; Lee, 2012). Tests designed to detect parenting effects on self-control in children are, almost invariably, observational in nature. Parenting strategies are often not easily subjected to the types of experimental control possible using random assignment between treatment and control groups (Lee, 2012; Rohrer, 2018). A study testing for possible child-driven effects, moreover, would be similarly unable to randomly manipulate levels of self-control in children. Statistical control then becomes the necessary alternative. And for several reasons detailed below, this approach struggles to overcome the key challenges in the pursuit of detecting valid causal effects.

The first challenge is overcoming familial confounding. Familial confounding occurs when an association that is observed between family members is spuriously attributed to the family environment, but is in fact due to an omitted variable that affects more than one member of the family. For example, in studies related to parenting in particular, confounding factors of this nature might include socioeconomic status and certain neighborhood qualities, and attempts are made to capture these factors with key controls in various regression equations (Anderson et al., 2015; Lee, 2012; Ng-Knight & Schoon, 2017; Stults & Swagar, 2020; Thompson et al., 2020). The problem, though, is that familial confounding emerges in more than one form, and one of those forms is less easily dealt with when using traditional social-science methods (Barnes et al., 2014). When familial confounding assumes the form of *genetic* confounding, it reflects the tendency for parents and offspring to resemble one another owing, in part, to shared genetic material (Lee, 2012). The consequence of this is that phenotypic correlations between parents and children might disguise themselves as being purely environmental, when at least some portion of the phenotypic correlations is owed to genetic factors that are shared between parents and children (Barnes et al., 2014). Observational data cannot easily deal with familial confounding, at least not in the elegantly simple way that experimental designs do. This does not mean that observational data offers no benefit—however, it does mean that observational data drawn from families must include twins or adoptive offspring to account for genetic confounding.

To further understand the need for such data, it should first be pointed out that environmental effects can actually be divided into two varieties: shared and nonshared (Barnes et al., 2014). Shared environmental effects are those that cause family members to be more phenotypically similar. In contrast, non-shared environmental effects include any factor that leads to family members being less similar. Together with heritability, these two types of environmental influences explain trait variance for any outcome of interest (Plomin et al., 2008). In an adoption study, nonshared environmental effects manifest in the differences between siblings raised together, while also capturing the presence of measurement error. Shared environmental factors create similarities between siblings in the same family. Heritable influences reflect the role of genetic variation in explaining trait variation in a population. Studies lacking the appropriate data will necessarily conflate each of these components into a single phenotypic effect (Barnes et al., 2014).

A Brief Aside on Aggression

Closely intertwined with the development of self-control is the ability to regulate overtly antisocial and aggressive behaviors. While expressing an aggressive urge can provide momentary gratification, restraining those impulses may aid in avoiding repercussions and possible regret. Self-control plays a key role in aggressive behavior in that it can act to directly to inhibit it (Denson et al., 2012; DeWall et al., 2011). Given their interconnection, it is no surprise that positive parenting behaviors have been consistently found to be negatively correlated with aggressive behavior in offspring (Özdemir et al., 2013). The interesting twist here, however, is that in contrast with self-control, variance in aggression does seem to involve shared environmental factors, as opposed to the largely heritable and nonshared effects seen with self-control (see Burt et al., 2009). Sibling designs are necessary if we are to avoid conflating these environmental and genetic effects and arriving at a possibly erroneous conclusion concerning causality. In the current study, we approached the problem by analyzing the relationship between self-control, as well as aggression, and parenting in a longitudinal sample of nonadoptive and adoptive families.

An Overview of the Current Study

The current study seeks to further understand the causal nature of the relationship between parenting and self-control (or aggression), including any role (confounding or otherwise) that a shared genetic basis may play. Although the results of Li et al. (2019) suggest that the association between parenting and self-control is (reciprocal and) causal, it is possible that the association is actually a consequence of genetic confounding. Do children's level of self-control reflect the level of parenting they perceive? Or do the same genetic factors that influence parenting behaviors also play a role in the manifestation of children's self-control? To what extent do genetic or environmental factors account for the association that is observed between parenting and self-control?

To this end, we examine the role that parenting activities might play in the development of children's self-control and aggression at two time points, early and late adolescence, using a genetically sensitive design. The main purposes are to 1) affirm the prevailing literature on the relationship between self-control (or aggression) and parenting, and 2) to clarify the genetic nature of the associations between the variables. We employ both standard social-science methods and behavior-genetic methods. The social-science methods were used in the full sample regardless of the participant's adoptive status, to ascertain the phenotypic associations between self-control and parenting. For each standard social-science method, the tests were repeated in both the nonadoptive and adoptive families to find if differences arise between the subsamples, differences which could be attributed to genetic relatedness. Behavior genetics methods are employed to fully utilize the adoptive study design. These methods allow us to find the extent to which genetic and environmental sources play a role in the development and relationship between self-control (or aggression) and parenting. The latter variable is measured by the Parental Environment Questionnaire (Elkins et al., 1997). Here, a high level of parenting is defined by a lack of parent-child conflict, children's regard for their parents, children's perception of their parents' regard for them, and structure provided by their parents. Parenting is treated as a characteristic of the children rather than of the parents.

We hypothesize the following:

Hypothesis 1: Based on the extant literature, it is anticipated that (a) parenting associates with self-control (or aggression) such that higher levels of parenting correlate with higher levels of self-control (or with lower levels of aggression) within and across time points, and (b) any significant associations should be comparatively stronger in the nonadoptive relatives, as opposed to the adoptive relatives.

Hypothesis 2: Children's genetic factors account for a portion of the variance in levels of self-control, aggression, and parenting.

Hypothesis 3: Children's genetic factors account for a portion of the covariance between levels of self-control (or aggression) and parenting.

Methods

Participants

The data for the current study were drawn from the Minnesota Center for Twin and Family Research: Sibling Interaction and Behavior Study (SIBS). This study consists of 409 adoptive and 208 nonadoptive families. Adoptive families were recruited through private adoption agencies, and nonadoptive families were recruited through birth records.

Each family was comprised of a pair of siblings and two parents. At intake, families completed a half-day assessment that included questionnaires and interviews. At follow-up, assessments were taken in-person or over the telephone. In 285 of the 409 adoptive families, the siblings were genetically unrelated, and both were adopted; in the remaining 124, only one sibling was adopted, and the other was genetically related to at least one of the parents. After applying inclusion criteria, there were a total of 1,164 parents and 1,232 offspring at intake. In the first follow-up, 84% of participants were re-assessed on self-control and aggression, and 92% on parenting. See Table 2.1 for descriptive statistics.

A comparison of non-participants to participants at the first follow-up revealed no significant difference between the two groups. Non-participants did not differ in their levels of self-control, aggression, or parenting at wave 1 compared to those of the returning participants. Returning participants were not more likely to be from any key demographic groups (such as sex, race, adoptive status, or socio-economic status). See Supplementary Table 2.1 for the full results of attrition analyses.

Ninety-five percent of all parents of the sample were White, which was representative of the composition of Minnesota at intake. The sample itself was 56% White, 39% Asian, 4% multiracial, and 1% Black. In families with one or two adoptive children, the sibling pairs were composed of 96 male/male, 148 female/female, and 163 male/female. The adoptive children were primarily Asian (69%) or White (25%). In nonadoptive families, sibling pairs were 62 male/male, 68 female/female, 78 male/female. Nonadoptive children were primarily White (96%) with the remaining subsample being either Black or multiracial. At initial assessment, siblings had a mean age of 15. In the subsequent first follow-up, the siblings had a mean age of 18. An overview of the sample at intake (wave 1) and follow-up (wave 2) are shown in Table 2.2. Additional information about the SIBS sample can be found in McGue et al. (2007).

Measures

Self-Control. In this sample, self-control was measured using the Control (versus Impulsivity) scale from the Multidimensional Personality Questionnaire (MPQ) or the Personality Booklet – Youth Abbreviated (PBYA). The MPQ is a self-report questionnaire that was developed via factor analysis to measure higher- and lower-order personality traits. The PBYA is a shortened version of the MPQ that is designed for adolescents under 16 years of age. The Control scale, which is presented in both the MPQ and PBYA, is designed to assess a person's tendency to be cautious, contemplative, and responsible. This scale has been shown to be related to substance use and antisocial personality disorder, as well as a direct measure of behavioral disinhibition (McGue et al., 1999; Sach et al., 2018). Hereafter, we refer to this scale as self-control, which consists of 18 items with a 4-point response format from 'Definitely True' to 'Definitely False.' Items included: "I like to stop and think things over before I do them," "I almost never do anything reckless," and "I often act on the spur of the moment (reverse-scored)". See Table 2.2 for descriptive statistics and reliability.

Aggression. Aggression was measured using the Aggression scale of the MPQ and PBYA. Aggression is defined as a person's willingness to harm others for selfish reasons. The scale consists of 18 items with a 4-point response format from 'Definitely True' to 'Definitely False.' Items included: "Often when I get angry I am ready to hit someone," "I can't help but enjoy it when someone I dislike makes a fool of herself/himself", and "When people insult me, I try to get even." See Table 2.2 for descriptive statistics and reliability.

Parenting. Parenting was measured using the Parental Environmental Questionnaire which assesses parent-child relationships for each specific child within a family. The offsprings rated 50 items assessing their relationship across five dimensions on a 4-point scale from 'Definitely True' to 'Definitely False.' These dimensions include parent-child conflict, parental involvement with child, child regard for the parent, parent regard for the child, and structure provided by the parent. Full information is detailed in Elkins et al. (1997). Structure provided by the parent was measured at wave 1, but not wave 2. In these analyses, structure has been excluded for that reason. The dimensions of the PEQ were first summed; then the average rating for the mother and father was taken to create one parenting variable per participant. The correlation between the offspring's rating of the mother and father were large and significant at wave 1 and wave 2 (r = .73, $p < .001$), suggesting a common bias in offspring's ratings of the two parents or in the parents response to the behavior of the offspring. See Table 2.2 for descriptive statistics and reliability.

Statistical Analyses

In order to analyze the relationship between parenting and self-control (and aggression), a mixture of standard and biometric methods were utilized. Standard methods were used to test hypothesis 1. Our first step was to analyze the correlations among all variables at both time points. These correlations were conducted to assess the extent to which self-control (or aggression) associates with parenting for all participants. We also employed correlations to examine the extent to which sibling pair types (adoptive vs nonadoptive) resembled one another on all variables. Age and sex were regressed out.

Next we analyzed the longitudinal relationships between the variables by conducting a cross-lagged panel model. Cross-lagged panel modeling is a technique that utilizes longitudinal data to test the reciprocal associations between two constructs within and across time points. “Cross” refers to the comparison of separate variables, and “lagged” refers to the measurement of variables across time points. The “cross-lagged” relationship between wave 1 self-control (or aggression) and wave 2 parenting was compared to the relationship between wave 1 parenting and wave 2 self-control (or aggression). Cross-lagged panel models also account for synchronous relationships between the variables within the same time point and autoregressive effect (or stability) of a trait across time points. The cross-lagged panel models were estimated using the *lavaan* package in *R*. Variables were corrected for age and sex before entering the model. Standard errors were adjusted for sibling clustering.

Then, to take advantage of our genetically informative sample consisting of both nonadoptive and adoptive families, we examined the extent to which genetic variance could partly inform any associations between variables by first calculating univariate ACE decompositions. The ACE model is a behavior-genetic method capable of decomposing phenotypic trait variance into additive genetic (A) and environmental components that are shared (C) or non-shared (E) between relatives. Nonadoptive sibling pairs are assumed to share half of their additive genetics by descent and all the shared environmental variance. Adoptive sibling pairs are assumed to have only the shared environment in common. This technique allowed us to test hypothesis 2 by calculating the degree to which A, C, and E components contribute to the overall variance in a measured construct. A graphical depiction of this ACE model is presented in Figure 2.1.

Beyond the univariate models, we also calculated bivariate Cholesky models (Neale et al., 2006) to test hypothesis 3. Like the ACE model, bivariate Cholesky models decompose variance into the A, C, and E factors, but the Cholesky also decomposes the covariance between two variables into genetic and environmental factors. Using this technique, therefore, we can estimate the degree to which genetic and environmental influences explain the phenotypic correlations between the variables. A graphical depiction of this model is presented in Figure 2.2. In estimating both the ACE and Cholesky models, alternative model specifications were considered. First the full ACE model was estimated, and fit statistics from this model were compared to nested models (i.e., AE, CE, and E models). Fit statistics included chi-square (χ^2) statistic and AIC statistic. If a nested model provided a significantly different χ^2 or a smaller AIC valued compared to that of the full ACE model, the nested model was chosen over the full. All biometric models were estimated using *OpenMx* in *R*.

Results

Correlational Analyses

Table 2.3 presents the correlation estimates for self-control, aggression, and parenting at waves 1 and 2 for the entire sample regardless of adoptive status. Self-control at wave 1 correlated with parenting at wave 1 (r = .09, p = .002) and wave 2 (r = .09, p = .005). Wave 2 self-control correlated with parenting only at wave 2 (r = .10, p = .002). These results suggest that self-control and parenting may be associated at within the same time point, but not across time points. Aggression showed a similar pattern of association with parenting: correlations between aggression and parenting were significant within wave 1 (r = -.12, p < .001) and wave 2 (r = -.09, p = .004), but not across waves.

These correlations were also examined by subsample, specifically by each participant's adoptive status. These correlations were calculated to determine if differences emerged between offspring who were raised by nonadoptive or adoptive parents. Table 2.4 presents the correlation estimates for self-control, aggression, and parenting across both waves for all individuals in nonadoptive families, and Table 2.5 for the individuals in adoptive families. In the subsample of nonadoptive families, self-control at wave 1 did not significantly correlate with parenting at wave 1 and wave 2. Self-control at wave 2 did correlate with at parenting wave 2 (r = .14, p = .002), but not wave 1.

Self-control at wave 1 did not significantly correlate with parenting at wave 1 or wave 2 in the adoptive families. Likewise, self-control at wave 2 did not significantly correlate with parenting at either wave. In the terms of aggression, in the nonadoptive families, aggression and parenting did not significantly correlate within or across time points. In contrast, in the adoptive subsample, aggression at wave 1 significantly correlated with parenting at wave 1 (r = -.14, p < .001) as well as wave 2 (r = -.12, p = .005). Wave 2 aggression did not significantly correlate with parenting at either wave.

Next we examined the intraclass correlations of self-control and aggression as a function of sibship type (i.e., nonadoptive or adoptive status; see Table 2.6). These correlations indicate the extent to which one sibling's level of self-control (or aggression) resembles that of their sibling. In regards to self-control, at wave 1, nonadoptive siblings had a modest resemblance ($r = .16, p = .022$), while adoptive siblings showed little to no resemblance ($r = .05, p = .730$). Results indicated that both nonadoptive and adoptive siblings had a nonsignificant correlation at wave 2, but surprisingly, the correlations were negative ($r = -.13, p = .099$; $r = -.11, p = .073$). In the full sample, this negative association was significant ($r = -.12, p = .009$). In comparison, both nonadoptive and adoptive siblings shared a small to moderate resemblance in terms of their level of aggression. Correlations between nonadoptive siblings were significant at wave 1 ($r = .34, p < .001$) and wave 2 ($r = .30, p < .001$). Adoptive siblings also had a small, but significant resemblance at both waves 1 and 2 ($r = .12, p =.018$; $r = .12, p = .041$).

Cross-Lagged Panel Models

The cross-lagged panel models are displayed in Figures 2.3 and 2.4. Figure 2.3 shows the standardized parameter estimates for the associations between self-control and parenting at waves 1 and 2, and Figure 2.4 displays the estimates between aggression and parenting at waves 1 and 2. Part A of each figure presents the estimates for the available sample regardless of the individual's adoptive status, Part B the nonadoptive subsample, and Part C the adoptive subsample. The effects of age and sex were regressed out before entering the models.

As can be seen in Figure 2.3, in the full sample, the cross-sectional associations (i.e., the associations across traits within the same time point) between self-control and parenting were small, but significant ($p < .05$), suggesting that children with higher scores on self-control perceived that they had higher parenting within the same wave. The cross-sectional paths were also small, but significant in the nonadoptive subsample; however, no cross-sectional path was significant in the adoptive sample. Across the overall sample and the subsamples, the autoregressive paths (i.e., the associations of a trait with itself across time points) were moderate and significant, with each variable at wave 1 associated with itself at wave 2, thus providing evidence for a degree of temporal stability in the measures across time. Across the overall sample and subsamples, no cross-lagged paths (i.e. the associations across constructs and time points) were significant. Together, these finding suggests that parenting and self-control may influence the other within the same time point, but neither trait is predicted by or predictive of the other.

A similar pattern of findings emerged for aggression and parenting, as shown in Figure 2.4. All autoregressive paths were significant ($p < .05$) in the full sample and the subsamples, indicating a degree of temporal stability. However, while the cross-sectional paths were significant ($p < .05$) in the full sample, only the cross-sectional path at wave 2 was significant in the nonadoptive subsample and only at wave 1 for the adoptive subsample. As observed with self-control, no cross-lagged path was significant, providing no evidence that longitudinal influences emerge in this sample regardless of adoptive status.

Biometric Analyses

Univariate ACE models. For the biometric analyses, the variance in the self-control and aggression measures were decomposed into genetic and environmental components. A series of univariate ACE models were estimated, the results for which can be found in Table 2.6. Estimates for four separate ACE models are presented along with the fit statistics for the best-fitting model. Beginning with wave 1 self-control, the best-fitting model revealed that 30% of the variance was explained by additive genetic factors, 2% by the shared environment, and 68% by the nonshared environment. The model for wave 2 self-control suggested no additive genetic or shared environmental effects. While this finding does align with the sibling correlations at wave 2 (seen in Table 2.5), all models in which an A or C effect were included indicated that both effects were negative, which is impossible. Thus, while the best-fitting model for wave 2 self-control was a CE model, the E model is presented, as all tested models suggested that the shared environment captures the totality of the variance.

The results for wave 1 aggression indicated that the variance was explained by the full ACE model: additive genetic influences contributed 45%, the shared environment 12%, and the nonshared environment 43%. Similarly, the best-fitting model for wave 2 aggression attributed variance to additive genetic (38%), shared environmental (12%), and nonshared environmental influences (51%).

Cholesky models. Next, we further examined the sources of covariance between self-control (or aggression) and parenting. To this end, a series of bivariate Cholesky models were estimated. Although it was planned to estimate the bivariate Cholesky model for self-control at wave 2, this analysis was dropped due to the unexpected results of the univariate analysis which indicated that self-control had no genetic influences at this wave. A bivariate analysis of wave 2 self-control was made moot due to the impossibility of calculating a genetic correlation for trait that shows no evidence of heritability. The results for the bivariate Cholesky models of wave 1 self-control (or aggression) at both waves, and parenting at wave 1 is presented in Table 2.8. Table 2.9 displays the results for parenting at wave 2. Only the estimates for the covariances are shown, and the univariate portion of the model is omitted for the sake of parsimony as the results were substantively similar to the univariate ACE models.

One general conclusion can be drawn from Table 2.8 (covariances of wave 1 parenting and self-control, or aggression), which is that shared additive genetic factors explained much of the overlap between each of the variable pairings. Shared environmental influences explained the next largest portion of the overlap, although these influences were not significant for wave 1 self-control. The remainder was explained by nonshared environmental influences, which were insignificant across all analyses.

Covariances of wave 2 parenting and the other variables, as displayed in Table 2.9, showed a different pattern of results. Specifically, the covariance between wave 1 self-control and wave 2 parenting appeared to be due to environmental factors alone, with the nonshared environment capturing most of the covariance. This was also the case for wave 2 aggression and parenting. For wave 1 aggression and wave 2 parenting, the overlap was largely explained by shared additive genetic and shared environmental factors, and the rest by the nonshared environment. However, neither the additive genetic nor nonshared environmental influences were significant.

Discussion

This study analyzed the relationships between self-control (or aggression) and parenting during early and late adolescence. Analyzing a sample of nonadoptive and adoptive children allowed for the estimation of genetic and environmental influences on self-control and aggression, as well as the covariance between those measures and parenting. We had several aims. The first aim was to test the prevailing literature that asserts that self-control and parenting are associated in a reciprocal causal manner. The second aim was to calculate the extent to which the association could be attributed to shared genetic influences rather than environmental ones.

Three broad findings emerged. Although parenting was significantly associated with self-control and aggression within a wave of measurement at the phenotypic level, there was little evidence to suggest that parenting had a longitudinal causal influence on self-control. Variance in self-control appears to have a small genetic component in early adolescence, with decreases in late adolescence, accompanied with an increasing relevance of the nonshared environment. Across both self-control and aggression, as well as their covariance with parenting, the shared environment played a substantively small role.

The first hypothesis asserted that higher levels of parenting should associate with higher levels self-control, or low levels of aggression, within and across time points and that the associations should be comparatively stronger in the nonadoptive subsample than the adoptive subsample. This hypothesis was not fully supported. While self-control and aggression did significantly correlate with parenting within the same time point in the full sample, they did not significantly correlate across waves with the exception of wave 1 self-control and wave 2 parenting. In the nonadoptive subsample, apart from the correlation between self-control and parenting at wave 2, parenting did not significantly correlate with either self-control or aggression. In the adoptive subsample, there were no significant correlations between parenting and self-control, but wave 2 aggression did significantly correlate with both waves of parenting. These results were not expected. Li et al. (2019) and Mueller et al. (2022) found that parenting influences self-control during adolescence. If self-control (or aggression) and parenting share a considerable genetic basis, then the influence of parenting on self-control (or aggression) should be larger in the nonadoptive subsample. And therefore, while this association is not expected to be completely absent in adoptive children, since parenting may influence self-control (or aggression) through the environment, it was anticipated that the association would be relatively weaker in the adoptive subsample.

The unusualness of the results observed in these individual-level correlations were corroborated by the results of the other standard social-science methods. When examining the correlations between siblings by sibship type, it was found that nonadoptive siblings' levels of self-control were positively correlated, while adoptive siblings' were not—which was expected. However, at wave 2, siblings of either type showed no resemblance. The correlations, though insignificant, were negative. And in the full sample, the negative correlation was in fact significant. This outcome suggested that there was little to no genetic influence on self-control at wave 2, which was a wholly surprising result.

Evidence from the cross-lagged panel also aligned with the results of the individual-level correlations: while all autoregressive correlations were significant, synchronous paths were significant in only the nonadoptive subsample and no cross-lagged path reached significance regardless of sample type. The cross-lagged panel models of aggression and self-control generally displayed a similar pattern of results. Unlike self-control, however, the correlations between siblings' levels of aggression indicated that both nonadoptive and adoptive siblings significantly resembled one another at both waves of measurement. That resemblance appeared to be stronger between the nonadoptive siblings. This finding suggested that genetic influences have some effect on aggression.

To formally test the second hypothesis, that genetic factors account for the variance in the measured traits, univariate analyses were conducted. As with hypothesis 1, hypothesis 2 was partially supported. For wave 1 self-control, the best fitting model suggested that both genetic and nonshared environmental influences explained significant portions of the variance. However, in Wave 2, model comparisons pointed to the variance in self-control being wholly attributable to the nonshared environment (or measurement error). Though these results were unexpected, they do align with the phenotypic correlations which were positive/significant for nonadoptive sibling pairs at wave 1 and negative/insignificant at wave 2. The lack of heritable influences uncovered here contrasts with the findings of Mueller et al., (2022) who found that genetic factors accounted for about 53% of the variance in late adolescence. In contrast to self-control, we found that siblings' levels of aggression did increase in similarity over time and that aggression was influenced by genetic and environmental factors at both waves 1 and 2, with heritability and the nonshared environment capturing about 40-50% of the variance. More research here is necessary to further clarify the etiological development of personality over time; it would be interesting for future research to examine how specific traits or facets develop as most research thus far has focused on larger domains of personality.

Our third primary hypothesis, that the covariance between self-control and parenting would be primarily attributable to genetic factors, was only partly supported by the results of the bivariate Cholesky models. This supposition only held in wave 1 parenting and wave 1 self-control. In wave 2 parenting, no significant heritable effects were detected, and nearly all of the covariance was explained by the nonshared environment. It was also found that a small contribution of shared environmental factors to the covariance between parenting and self-control at waves 1 and 2, suggesting that parenting does not increase sibling resemblance. Parenting and aggression had similar results, with the exception of wave 2 parenting and wave 1 aggression, which had a significant and moderate shared environmental component. Overall, the results of this study suggest that the influence of parenting, limited as they might be, will likely manifest via the nonshared environment. Differences in parenting between children, or the offspring's perception of such, may *cause* nonadoptive family members to become dissimilar over time—at least during the transition to adulthood.

Limitations

There were several limitations to consider when interpreting the results. First, there are other environmental variables that were not included in this study that could explain the relationships observed. Second, ethnicity and adoptive status was largely conflated in this sample, with Asians over-representing the adoptive subsample and Whites over-representing the nonadoptive subsample. However, ethnicity was not indicated to be associated with the variables of this study (standardized mean differences were negligible, $d < .20$). Third, we were not able to explore for the potential presence of nonadditive genetic effects given the nature of our sample. In personality research, many studies have found the existence of nonadditive or dominance effects, including in our measurement of self-control (Matteson et al., 2013). Future research should extend this work using a twin-adoption sample to be able to properly detect the presence of nonadditive genetic factors.

Conclusion

Overall, the results of this study were not wholly foreseen. Though the hypotheses were partially supported, the relationships that were expected to exist between self-control and parenting, in particular, were not observed. This study was based on the premise that self-control and parenting would be significantly associated. Furthermore, we presumed that the traits would be heritable (or genetically influenced) at both waves. Thus, we hypothesized that the existing associations between these variables could be explained, at least partially, by a shared or overlapping genetic basis. However, self-control at wave 2 did not appear to be heritable, and indeed, the sibling correlations at that wave were negative. We did find evidence against a causal relationship, but we also did not find evidence for genetic confounding, as genetic confounding cannot occur if a trait is not genetically influenced. Considering these results, we do not contend that these findings are representative of the true nature of self-control and its relationship with parenting. Rather, it may be the case that the sample used here represents a unique sampling of individuals in whom a robust relationship between self-control and parenting do not exist.

Though the findings are unexpected and have their limitations, this study nevertheless illustrates the way in which genetically sensitive designs—in this case, data including adoptive children—can help to clarify the possible causal effects that various aspects of parenting might have on child development. There is growing recognition in the developmental field that genetic and environmental factors are entwined in family studies unless they are controlled for. Adoption studies allow us to take on a more granular approach when examining the influence of parenting. How do parents influence their children? Is this influence environmental? And if so, does it result in children who more similar to one another or less? Our findings suggest that the associations of self-control and aggression with self-control are nuanced. While we found evidence that parenting influences self-control and aggression at the phenotypic level, the effects did not emerge over time in the longitudinal models. Genetic factors had some influence on self-control and aggression in early adolescence, but it appeared to wane in late adolescence, a period during which the nonshared environment played the principal role. Like many other personality traits, the shared environment seemed to have little to no influence on self-control or aggression. We encourage future research to further examine the etiology of self-control and parenting by using more powerful samples and methods.

Table 2.1

Description of Sample by Adoptive Status

Subsample	Wave 1					Wave 2				
	N	% Female	*M* Age (SD)	Race %	SES *M*	*N*	Female %	*M* Age (SD)	% Race	SES *M*
Nonadoptive	692	55%	14.9 (1.9)	69% Asian 25% White 4% Multiracial 2% Black	-.24	489	57%	18.3	69% Asian 25% White 4% Multiracial 2% Black	-.22
Adoptive	539	54%	14.9 (1.9)	96% White 3% Multiracial < 1% Black	.19	638	55%	18.1 (2.0)	96% White 3% Multiracial < 1% Black	.18

Note. Number of individuals listed represents those with valid scores on self-control, aggression, or parenting. Socioeconomic status (SES) was calculated as an overall *Z*-score based on parents' level of education, occupation, and family income.

Table 2.2

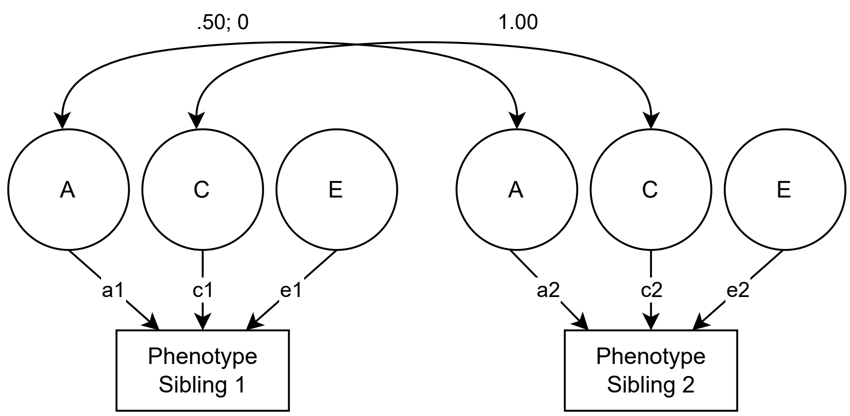
Descriptive Statistics and Reliability for Self-Control, Aggression, and Parenting

Variable	N	*M*	*SD*	α	ω_h	ω_t
Self-Control Wave 1						
MPQ	317	47.0	8.7	.88	.61	.90
PBYA	896	46.3	8.4	.86	.66	.88
Total	1213	46.5	8.5	.72	.85	.85
Self-Control Wave 2						
MPQ	839	47.4	8.6	.89	.70	.90
PBYA	178	47.0	7.9	.87	.55	.89
Total	1017	47.3	8.5	.86	.44	.93
Aggression Wave 1						
MPQ	320	38.5	10.6	.92	.74	.93
PBYA	896	39.2	10.5	.91	.80	.92
Total	1216	40.0	10.5	.91	.56	.94
Aggression Wave 2						
MPQ	841	37.1	10.2	.91	.76	.93
PBYA	177	37.1	9.5	.91	.81	.92
Total	1018	37.1	10.0	.86	.58	.95
Parenting Wave 1	1159	107.2	7.1	.97	.70	.98
Parenting Wave 2	1062	107.0	7.5	.97	.77	.98

Note. MPQ = Multidimensional Personality Questionnaire, PBYA = Personality Booklet – Youth Abbreviated, N = sample size, α = Cronbach's alpha. ω_h = omega hierarchical, ω_t = omega total. Self-control and aggression scores ranged from 18 – 72. Parenting scores ranged from 40 – 160.

Figure 2.1

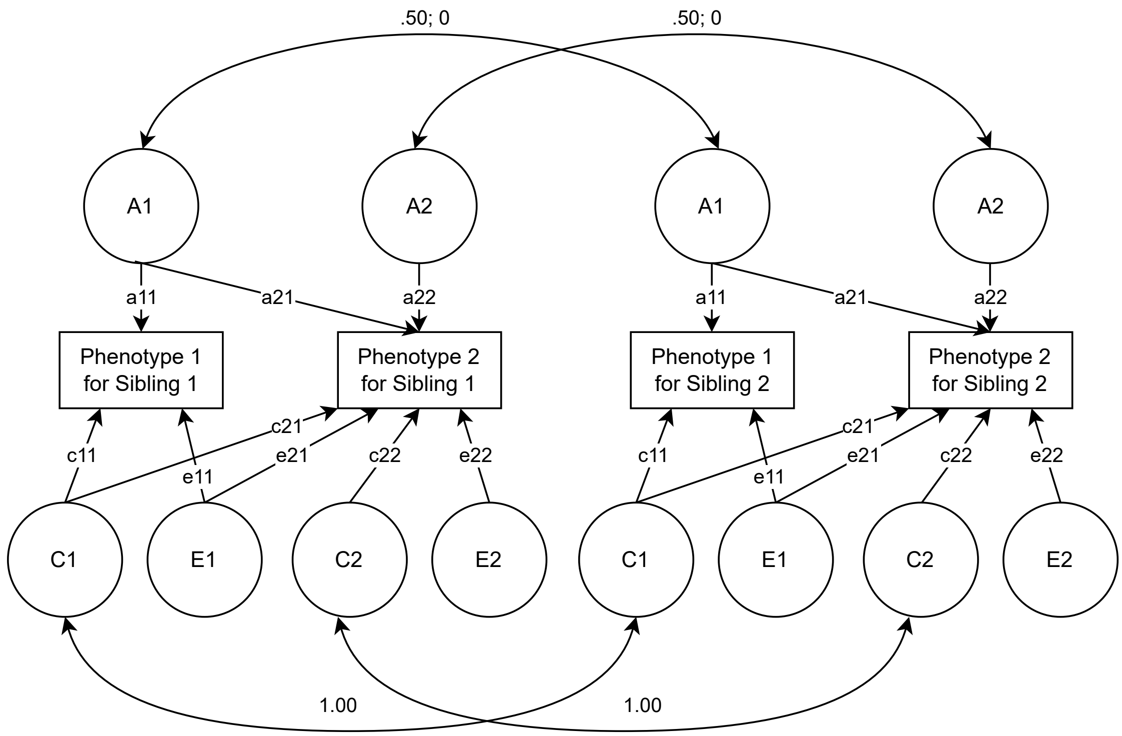
Diagram of Univariate ACE Model of Siblings



Note. Correlations between nonadoptive and adoptive siblings are compared based on the difference in the proportion of genetic material shared. On average, nonadoptive siblings share 50% of their DNA by descent; adoptive siblings share none. These correlations allow the estimation of the relative contribution of additive genetic effects (a1), shared environmental effects (c1), and nonshared environmental effects (and measurement error; e1) to the variance.

Figure 2.2

Diagram of Bivariate Cholesky Model



Note. The variance in a given phenotype at each wave is parsed into what is due to additive genetic effects (A1, A2), shared environmental effects (C1, C2), and nonshared environmental effects (E1, E2). The paths (e.g., a11, a21, a22) are squared to estimate the proportion of variance accounted for.

Table 2.3

Correlations Among Self-Control, Aggression, and Parenting at Waves 1 and 2 Regardless of Adoptive Status

Variable	1	2	3	4	5
1. Self-Control Wave 1					
2. Self-Control Wave 2	**.56** [.51, .62]				
3. Aggression Wave 1	**-.46** [-.51, -.39]	**-.31** [-.38, -.24]			
4. Aggression Wave 2	**-.31** [-.38, -.23]	**-.43** [-.50, -.35]	**.58** [.52, .64]		
5. Parenting Wave 1	**.09** [.02, .17]	.04 [-.03, .14]	**-.12** [-.20, -.03]	-.06 [-.15, .01]	
6. Parenting Wave 2	**.09** [.01, .17]	**.10** [.02, .17]	-.06 [-.14, .02]	**-.09** [-.18, -.01]	**.44** [.37, .50]

Note. Correlations of available individual observations across waves and/or variables. Significant ($p < .05$) correlational values are in bold. Brackets show 95% confidence intervals (calculated using clustered bootstrapping). Sample sizes ranged from 934 to 1212 (see supplement for exact values of *N*).

Table 2.4

Correlations Among Self-Control, Aggression, and Parenting at Waves 1 and 2 in the Nonadoptive Subsample

Variable	1	2	3	4	5
1. Self-Control Wave 1					
2. Self-Control Wave 2	**.44** [.33, .54]				
3. Aggression Wave 1	**-.46** [-.54, -.36]	**-.19** [-.31, -.07]			
4. Aggression Wave 2	**-.26** [-.37, -.14]	**-.37** [-.48, -.27]	**.55** [.45, .63]		
5. Parenting Wave 1	.11 [.00, .21]	.08 [-.01, .20]	-.08 [-.19, .07]	-.04 [-.16, .07]	
6. Parenting Wave 2	.05 [-.06, .16]	**.14** [.03, .25]	.03 [-.09, .15]	-.08 [-.22, .06]	**.45** [.34, 55]

Note. Correlations of available individual observations across waves and/or variables. Significant ($p < .05$) correlational values are in bold. Brackets show 95% confidence intervals (calculated using clustered bootstrapping). Sample sizes ranged from 414 to 533 (see supplement for exact values of *N*).

Table 2.5

Correlations Among Self-Control, Aggression, and Parenting at Waves 1 and 2 in Adoptive Subsample

Variable	1	2	3	4	5
1. Self-Control Wave 1					
2. Self-Control Wave 2	**.64** [.58, .70]				
3. Aggression Wave 1	**-.45** [-.53, -.38]	**-.39** [-.48, -.31]			
4. Aggression Wave 2	**-.34** [-.43, -.24]	**-.47** [-.55, -.38]	**.61** [.53, .67]		
5. Parenting Wave 1	.08 [-.01, .18]	.02 [-.09, .12]	**-.14** [-.25, -.02]	-.07 [-.19, .02]	
6. Parenting Wave 2	.11 [.00, .21]	.07 [-.03, .16]	**-.11** [-.21, -.01]	-.10 [-.18, -.01]	**.44** [.34, .52]

Note. Correlations of available individual observations across waves and/or variables. Significant ($p < .05$) correlational values are in bold. Brackets show 95% confidence intervals (calculated using clustered bootstrapping). Sample sizes ranged from 519 to 679 (see supplement for exact values of *N*).

Table 2.6

Correlations of Self-Control and Aggression by Sibship Type

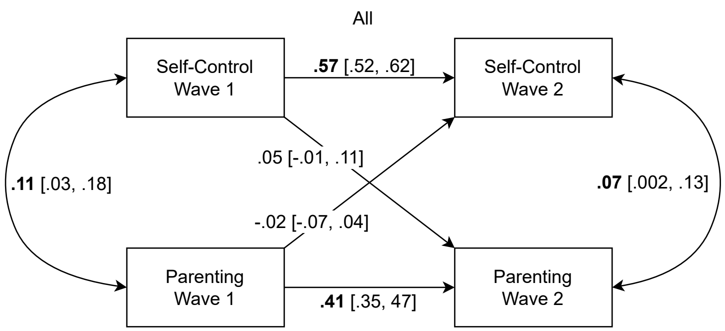
Variable	Wave 1			Wave 2		
	All	Nonadoptive	Adoptive	All	Nonadoptive	Adoptive
Self-Control	.06 [-.02, .14]	**.16** [.02, .29]	.05 [-.07, .17]	**-.12** [-.21 -.03]	-.13 [-.28, .02]	-.09 [-.22, .05]
Aggression	**.19** [.12, .27]	**.35** [.22, .46]	**.12** [.02 .21]	**.19** [.10, .27]	**.31** [.16, .44]	**.16** [.02, .28]

Note. Significant ($p < .05$) correlational values are in bold. Brackets show 95% confidence intervals. The number of nonadoptive sibling pairs ranged from 164 to 203, and 288 to 395 for adoptive sibling pairs (see supplement for exact values).

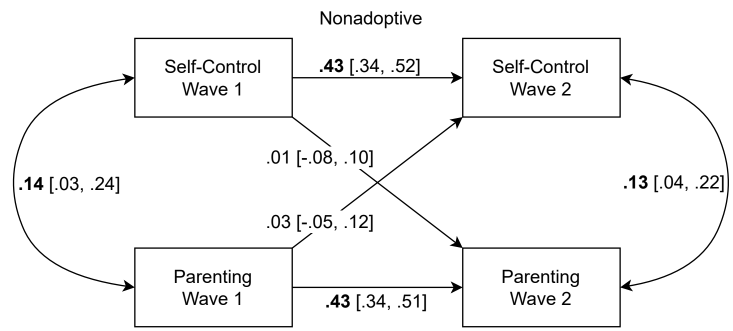
Figure 2.3

Cross-lagged Panel Model of Self-Control and Parenting

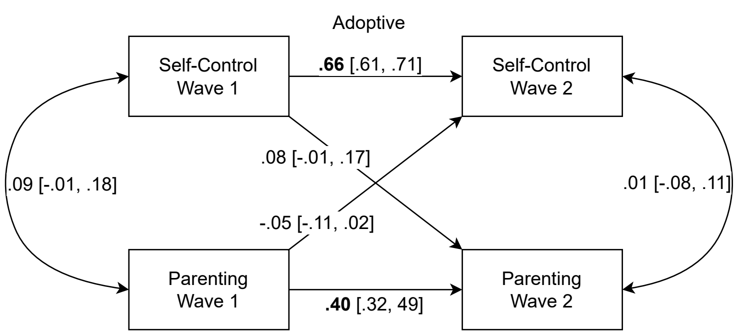
Part A.



Part B.



Part C.

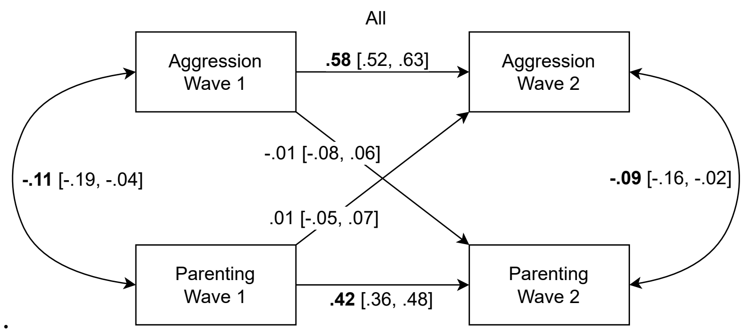


Note. Part A shows all individuals (*N* = 899). Part B shows the nonadoptive subsample (*N* = 402), and Part C the adoptive (*N* = 497). Standardized effects are displayed along with 95% confidence intervals. Bolded numbers represent significance ($p < .05$) Standard errors were corrected for clustering of siblings within families. Age and sex were regressed out before modeling.

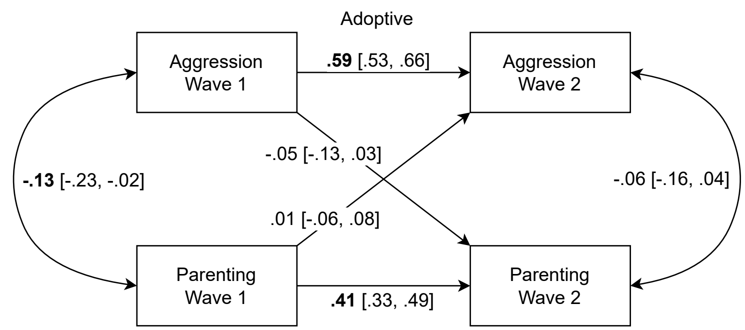
Figure 2.4

Cross-lagged Panel Model of Aggression and Parenting

Part A.



Part B.



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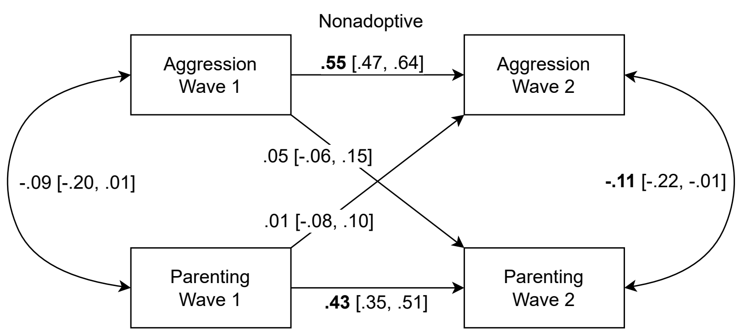
Part C.



Note. Part A shows all individuals ($N = 903$). Part B shows the nonadoptive subsample ($N = 403$), and Part C the adoptive ($N = 500$). Standardized effects are displayed along with 95% confidence intervals. Bolded numbers represent significance ($p < .05$) Standard errors were corrected for clustering of siblings within families. Age and sex were regressed out before modeling

Variable	Parameter Estimates						Model Fit Statistics			
	A		C		E					
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	χ^2	$\Delta\chi^2$	AIC	ΔAIC
Self-Control										
Wave 1	.30	[-.04, .62]	.02	[-.08, .12]	.68	[.42, 1.00]	8521.43	-	8539.43	-
Wave 2	-	-	-	-	1.00	[1.00, 1.00]	6953.44	2	6967.44	2.49
Aggression										
Wave 1	.45	[.15, .78]	.12	[.03, .22]	.43	[.17, .69]	8882.74	-	8900.74	-
Wave 2	.38	[.03, .71]	.12	[.01, .22]	.51	[.23, .81]	7128.48	-	7146.48	-

Table 2.7

Univariate ACE Model Parameter Estimates for Self-Control and Aggression by Wave

Note. Results from the best fitting model are shown. When the best-fitting model was the full ACE model, chi-square difference tests result and AIC difference values are shown, where the ACE model served as the reference.

Table 2.8

Bivariate Cholesky Model Parameter Estimates for the Covariance between Parenting at Wave 1 and Self-Control at Wave 1, and Parenting at Wave 1 and Aggression at Waves 1 and 2

	Parameter Estimates of Covariance with Parenting at Wave 1						Model Fit Statistics			
	A		C		E					
Variable	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	χ^2	$\Delta\chi^2$	AIC	ΔAIC
Self-Control										
Wave 1	.79	[.01, 1.40]	.17	[.00, .37]	.03	[-.50, .74]	17978.48	-	18016.48	-
Aggression										
Wave 1	.40	[-.25, .86]	.33	[.16 ,.49]	.27	[-.15, .80]	18366.81	-	18404.81	-
Wave 2	.59	[-.16, 1.35]	.30	[.08, .55]	.10	[-.52, .78]	15950.03	-	15990.03	-

Note. Results from the best fitting model are shown. When the best-fitting model was the full ACE model, chi-square difference tests result and AIC difference values are shown, where the ACE model served as the reference.

Table 2.9

Bivariate Cholesky Model Parameter Estimates for the Covariance between Parenting at Wave 2 and Self-Control at Waves 1 and 2, and Parenting at Wave 2 and Aggression at Waves 1 and 2

	Parameter Estimates of Covariance with Parenting at Wave 2						Model Fit Statistics			
	A		C		E					
Variable	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	χ^2	$\Delta\chi^2$	AIC	ΔAIC
Self-Control										
Wave 1	-	-	.26	[-.03, .50]	.74	[.50, 1.03]	16394.39	3.60	16428.39	2.40
Aggression										
Wave 1	.48	[-.31, 1.25]	.41	[.19, .66]	.10	[-.61, .79]	16801.26	-	16841.26	-
Wave 2			.33	[.16, 51]	.67	[.49, .84]	15781.15	3.40	15813.15	2.59

Note. Results from the best fitting model are shown. When the best-fitting model was the full ACE model, chi-square difference tests result and AIC difference values are shown, where the ACE model served as the reference.

STUDY 3

The Associations Between Openness/Intellect and Reaction Time

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ABSTRACT

This study examined the relationships among personality, intelligence, and reaction time. In particular, we investigated the structure of the Openness/Intellect domain from the Big Five Aspects Scale and how its aspects (Openness and Intellect) differentially relate to intelligence and to reaction time, as measured by two-choice reaction time paradigms. Given the extensive literature showing the association between Intellect (which involves intellectual curiosity) and intelligence, it was expected that Intellect associates most strongly with intelligence and with reaction time, which is a well-established correlate of intelligence. This study endeavored to further support the construct validity of Intellect and Openness, as two related but separable subfactors within their domain, using reaction time as an external criterion. In general, results from this study provide evidence that Intellect and Openness are distinct and may arise from independent biological sources. Further research is warranted to establish the discriminate validity of these aspects and disentangle the hierarchical structure of Intellect as it relates to intelligence.

Introduction

Intelligence and the nature of its relationship with personality has been fraught with disagreement. Intelligence has been argued to be entirely separate from personality; related to personality, but distinct from it; or a feature of personality. However, intelligence has consistently been shown to have meaningful relationships with the Big Five factors of personality, strongly suggesting that the first argument can be rejected (DeYoung et al., 2010; Stanek, 2014). Some models of the Big Five, such as the Big Five Aspects Scale (BFAS) model, have strongly supported the third argument (DeYoung et al., 2007). In the BFAS, each factor of the Big Five is partitioned into two lower-level aspects. Openness/Intellect is broadly related to cognitive exploration. As indicated by its label, it is comprised of two lower-order factors: Openness and Intellect. Openness relates to engagement with perception, fantasy, and aesthetics, while Intellect is defined as an individual's perceived intelligence or intellectual curiosity. Intellect is not equivalent to intelligence per se, but instead, intelligence may be one of many facets encompassed by Intellect.

The compound appellation of Openness/Intellect in the BFAS reflects the contentious process that characterized its construction. The earliest taxonomic studies, which often omitted descriptors of cognitive abilities or intelligence, first identified this domain as Culture (Norman, 1963; Tupes, 1958). Once such adjectives as *insightful* and *clever* were included, the domain was re-labelled as Intellect (Goldberg, 1990; John, 1990). The Intellect label was itself replaced by McCrae and Costa (1997), who found that the measures of intellectual interest co-varied with measures of aesthetic sensitivity. They argued that the domain should be called Openness to Experience, which is currently the most well-known designation.

The label of Openness to Experience specifically arose in the most predominant assessment of the Big Five: the Revised NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 2008). The original NEO began with analyses of Cattell's (1970) 16 Personality Factor Questionnaire, which was created using factor analysis of English words describing behavioral traits; the basis of this approach is known as the *lexical hypothesis*. Costa and McCrae initially decided on a three-factor model (Neuroticism, Extraversion, and Openness) until later research convinced them of the existence and importance of Agreeableness and Conscientiousness—which led to the invention of the NEO-PI. In 2008, Costa and McCrae added six facets under each of the Big Five factors using theoretical considerations and factor analysis. In the NEO-PI-R, Openness to Experience consists of ideas, feelings, values, fantasy, aesthetics, and actions.

Another common personality assessment is the Big Five Inventory (BFI). The BFI derived from the Adjective Check List by Gough and Heilbrun (1960), who consulted the works of Cattell and other prominent psychologists to determine the necessary words to describe a complete personality. A panel of expert judges then whittled that list to descriptors that were conceptually relevant to the Big Five. Soto & John (2017) extended the BFI model by including three facets under each domain. In the BFI-2, Open-Mindedness is comprised of intellectual curiosity, aesthetic sensitivity, and creative imagination.

The BFAS was created via factor analysis. A factor analysis of the NEO-PI-R and Goldberg's Abridged Big Five Circumplex scales from the International Personality Item Pool (Goldberg, 1999) was conducted by DeYoung et al. (2007), who found that a two-factor solution was produced for all domains. The two major subcomponents of

Openness/Intellect directly corresponded to Openness and Intellect. The BFAS model departs from the NEO-PI-R and the BFI-2 by holding that there exist aspects to the Big Five that occupy a level between the domains and facets, with a potentially innumerable number of facets falling under each of the aspects. Regardless of this difference, certain facets of the NEO-PI-R and the BFI-2 do align closely with the aspects of the BFAS. In Table 3.1 (C. J. Soto & John, 2017), a comparison of the aspects/facets of the Openness/Intellect domain by assessment is presented. The remaining facets of the NEO-PI-R and BFI-2 could be argued to represent a blend of the Openness and Intellect aspects.

The BFAS's use of the composite label (Openness/Intellect) remains appealing for its recognition that this domain can be subdivided into two major subfactors that are distinct, but correlated. Other pieces of evidence also suggest that Openness/Intellect may be composed of two subfactors as presented in the BFAS. Jang et al. (2002) found that there were two genetic factors that divided the heritable basis of each of the five domains in the NEO-PI-R. For Openness to Experience, the first genetic factor was marked by having a vivid imagination, an appreciation for beauty, and introspection, while the second was related to open-mindedness to new activities or ideas and intellectual curiosity. And similar to DeYoung et al. (2007), Woo et al. (2014) found evidence for two intermediate-level subfactors—between this domain and its facets—that they labelled Intellect and Culture. The intercorrelations of facets within one subfactor were observed to be higher than the intercorrelations of facets across subfactors. Despite the accumulating evidence, consensus has not yet been reached regarding the structure of this domain, and the topic warrants further research.

Intelligence and Openness/Intellect

Exploring the relationship of the Openness/Intellect domain to intelligence opens the opportunity to further validate the lower-level structure of this construct. Of all the Big Five traits, Openness/Intellect has been consistently found to most strongly associate with intelligence (Schwaba & Bleidorn, 2018). The correlation between Openness/Intellect and intelligence is about .30 (Ackerman & Heggestad, 1997). However, within this domain, the Intellect aspect ought to be more directly related to intelligence per its definition. And indeed, Intellect associates with general intelligence after controlling for Openness, but Openness only associates with general intelligence if Intellect is not controlled for (DeYoung et al., 2014). Nusbaum & Silvia (2011) found that only Intellect predicted nonverbal intelligence. The Openness and Intellect aspects have shown discriminant validity in regard to their relationship with intelligence.

The current study goes beyond the standard examination of intelligence and personality by exploring the associations of the Big Five with reaction time, a well-established correlate of intelligence. Reaction time is defined as the time taken to respond to a stimulus and is a measure of mental processing speed. Looking to external correlates to establish the discriminant validity of the Openness/Intellect domain, reaction time makes a promising prospect because of its relationship to intelligence—and because of the clear consensus that Intellect is more related to intelligence than Openness. If the intellectual features of the Openness/Intellect domain truly capture individual differences in intelligence, this domain (or one of its aspects) should reproduce the same, or similar, patterns of association as exist between intelligence and reaction time. And if such patterns of association arise, this study would provide evidence of the Intellect aspect being related to the cognitive/biological phenomenon of reaction time.

Reaction Time

Francis Galton was one of the first psychologists to research reaction time, which he proposed was negatively related to intelligence. His hypothesis was once regarded to be highly counterintuitive: reaction time was considered to be too trivial or inconsequential to correspond to intelligence in any way (Jensen, 1982). However, Galton's hypothesis has been long affirmed. It is now well-established that reaction time on simple cognitive tasks is related to general cognitive ability, possibly reflecting the speed with which the brain can process information. Individuals who score higher on cognitive ability tests tend to have faster, more accurate, and less variable reaction times (Deary et al., 2001; Hunt, 2005; Sheppard & Vernon, 2008). Across tasks that measure mental speed, the correlations between reaction time and intelligence are moderate, but consistent. In a literature review by Sheppard & Vernon (2008), the mean correlation between various measures of mental speed and intelligence was −.24 (SD = .07). As of yet, there is no unified theory that explains mechanistically how general cognitive ability is associated with speed of information processing. Nevertheless, reaction time has long been an instrument in experimental and cognitive psychology to tests ideas of attention, memory, and language. By investigating the relationship of reaction time with intelligence, researchers can explore the architecture of the mind:

> If the processing of information by the mind is highly structured, as most psychologists believe, then different paths through that structure will entail different time courses, and those differences will be reflected in the response

> times. Thus, perhaps, one can infer back from the pattern of response times obtained under different experimental conditions to the structures involved. (Luce, 1986, p. 1)

In reaction-time tasks that involve a two-choice decision, the diffusion model can be applied to explain the cognitive process behind a participant's behavior (see Figure 3.1; Vinding et al., 2021). In the diffusion model, the total reaction time is partitioned into two stages: the "diffusion" stage in which the decision is made and a non-decision stage. During the diffusion stage, a decision is reached by a noisy process in which information accumulates over time from a starting point toward one of the two thresholds for triggering a response (Ratcliff & McKoon, 2008). The rate at which the information accumulates is called the drift rate, which is thought to provide a pure measure of the speed of information processing. Unlike other parameters of this model, drift rate has been found to be related to intelligence (Schmiedek et al., 2007).

Reaction Time and the Big Five

Only a few studies have examined the relationship between personality traits and reaction time. These studies had small sample sizes ($n < 35$) and only assessed Extraversion and/or Neuroticism (Gupta & Nicholson, 1985; Stelmack et al., 1993). Extraversion and Neuroticism were expected to influence reaction time because of their association with impulsivity and the former's sensitivity to reward. The studies have conflicting conclusions regarding the relationship between the given personality trait and reaction time. In a study with a larger sample size ($n = 190$), Rammsayer et al. (2014) found that there was a main effect for Extraversion on mean reaction, with Extraverts possessing faster reaction times. Unfortunately, no study has yet examined how

Openness/Intellect might relate to reaction time—in part because this trait originated with the advancement and acceptance of the Big Five during 1990s and, possibly, due to the debate regarding the exact interpretation and contextualization of the Openness/Intellect domain.

The present study not only investigates the relationship between reaction time and personality, but also explores the construct validity of the BFAS. Is the conceptualization of the Openness/Intellect domain, in accordance with the BFAS, an accurate delineation of this personality trait? This study tests the discriminant validity of the BFAS model of the Openness/Intellect domain by examining the relationships of reaction time with the aspects of this domain. If reaction time correlates with Intellect, but not Openness, this finding would constitute further support for the construct validity of the Openness/Intellect domain consisting of two main subfactors.

The Current Study

In the present study, the relationships among personality, intelligence, and reaction time are investigated. Personality is assessed through the BFAS, and intelligence through the International Cognitive Ability Resource 16-item Sample Test (ICAR-16; Condon & Revelle, 2014). Reaction time is measured using two speeded cognitive tasks wherein a decisional manipulation is present. In the first task, participants are presented with a number (0 to 4 and 6 to 9) and must quickly decide if that number is greater than or less than 5. The decisional manipulation is the distance of the stimulus number from the target value of 5. In the second task, participants are presented with two tones and must decide if the second tone is higher or lower in pitch, with the decisional manipulation being a variation in the difference in the magnitude of the tones' pitches.

Since individuals with higher intelligence tend to come to the correct decision more swiftly, Intellect, as the aspect definitionally closer to intelligence, is expected to be negatively correlated with reaction time as well.

Unlike Intellect, Openness is not anticipated to correlate with reaction time. As per the BFAS model, Openness is a distinct aspect from Intellect. Definitionally, Openness is characterized by interest or engagement in the arts, imagination/fantasy, and perception rather than intellectual pursuits or complexity. Despite this expectation, however, it is within the realm of possibility that Openness will correlate to reaction time. Both Intellect and Openness relate to general curiosity, and Openness has been shown to associate with verbal intelligence, independent of Intellect (DeYoung et al., 2014). If the expectation of a null correlation between Openness and reaction time is confounded, the presence of the significant correlation may be explained by the Cybernetic Big Five Theory (CB5T; DeYoung, 2015).

The CB5T provides a mechanistic explanation of how personality produces goal-directed behaviors. Individuals who score highly on Intellect may have quicker reaction times because, as the CB5T proposes, Intellect relates to the detection of logical patterns. Therefore, individuals with high Intellect should hold an advantage over others in coming to the correct decision, across all levels of the decisional manipulation. The CB5T also proposes that Openness is distinguished from Intellect by being related to the detection of correlational patterns in sensory or perceptual information.

This division of Openness/Intellect into the ability to detect perceptual patterns and logical patterns shares parallels with one version of the diffusion model of reaction time. The diffusion model, in its simplest form, posits that reaction time can be partitioned into two discrete stages: a non-decision stage, which includes the time taken to perceive the stimulus, and a decision-making stage, which relates to the speed at which the information required to make a choice accumulates. If a trait is associated only with the non-decision stage, then it will associate with only speed (or a low mean reaction time). In contrast, if the trait is associated with the decision-making stage, it will associate with speed as well as variation in reaction times (or standard deviation) and accuracy (or the proportion of correct choices).

Several studies have found that individuals with a higher *g* have an advantage during this decision stage (James J. Lee & Chabris, 2013; Schmiedek et al., 2007). Thus, those with higher Intellect should similarly have lower mean reaction times, as well as lower standard deviations and higher accuracy. While it is not expected that Openness will correlate with mean reaction time, if this hypothesis does not hold true, Openness may correlate with mean reaction time because individuals with high Openness perceive the stimulus more quickly than those with low Openness. In such a case, Openness should only correlate with mean reaction time, and not with standard deviation or accuracy, since the latter do not relate to the decision-making stage. Thus, this ancillary hypothesis is proposed: if Openness does correlate with mean reaction time, it does not correlate with standard deviation or accuracy.

This assignment of Openness to the non-decision and Intellect to the decision stage can be further tested, in a manner requiring arguably fewer assumptions than diffusion modeling, by the method of additive factors (Sternberg, 1969). The method of additive factors is a procedure that can be used to demonstrate that a reaction time consists of two distinct stages. Suppose that there are two manipulations; the first manipulation only affects the first stage, and the second affects only the second stage. Then, together, both manipulations will have an additive effect on the overall process. Further suppose that there is a third manipulation (or naturally varying trait), which is associated with the first stage. Then, it is possible that the first and third manipulations may have an overall interactive effect.

The logic of this method applies here because it is expected that Intellect should have an interactive effect with decisional manipulation of the reaction time paradigms. In a reaction time study by Willoughby and Lee (2021), from which the paradigms used here originate, the relationship between reaction time and intelligence was examined; they found that there was a main effect between intelligence and the decisional manipulation, such that individuals with higher intelligence had faster average reaction times at every level of the decisional manipulation. These paradigms also test participants with a perceptual manipulation. In the number task, the stimulus varies in the strength of its contrast from the background. In the tone task, the volume of the second pitch is manipulated. Unlike with the decisional manipulation, Willoughby and Lee found that there was no interaction between cognitive ability and the perceptual manipulation.

Given the implications of the CB5T, the diffusion model, and the method of additive factors—as well as the results of Willoughby and Lee (2021)—the following are expected. Individuals with higher levels of intellect should be less hindered by the decisional manipulation (or the “distance” of the stimulus from the target), but not the perceptual manipulation (or “contrast” of the stimulus’s color from its background). There should be an interaction between Intellect and distance, but not between Intellect and contrast. While Openness is not anticipated to correlate with reaction time, if this expectation is not supported by the results, it is proposed that individuals with higher levels of Openness should be less hindered by contrast, but not distance. If Openness correlates with mean reaction time, Openness is expected to have an interactive effect with contrast and an additive effect with distance.

Overall, the main purpose of this study is to provide further validation of the Openness/Intellect hierarchy by examining the discriminant validity of Openness and Intellect aspects in relation to their associations with intelligence and reaction time. To this end, the following main hypotheses are tested:

> *Main hypothesis 1*. Of the Big Five personality domains, only the Openness/Intellect domain is positively correlated with cognitive ability. Within this domain, only Intellect is positively correlated with cognitive ability.
>
> *Main hypothesis 2*. Only Openness/Intellect is negatively correlated with mean reaction time in both the number and tone tasks. Within this domain, only Intellect is negatively correlated with reaction time.
>
> *Main hypothesis 3*. Intellect is negatively correlated with standard deviation and positively correlated with accuracy.
>
> *Main hypothesis 4*. Intellect has an interactive effect with distance on mean reaction time and an additive effect with contrast.

If main hypothesis 2 is not supported, in that Openness is correlated with mean reaction time, the following ancillary hypotheses are put forward:

Ancillary hypothesis 1. If Openness is correlated with reaction time, contrary to main hypothesis 2, Openness is correlated with only mean reaction time in the number and tone tasks. Openness is not correlated with standard deviation and accuracy.

Ancillary hypothesis 2. If Openness is correlated with reaction time, contrary to main hypothesis 2, it has an interactive effect with contrast and an additive effect with distance.

Methods

Participants

The sample for this study has been gathered via the Research Experience Program at the Department of the Psychology at the University of Minnesota ($N = 477$). The age range was restricted to ages between 18 to 24 ($M = 19.7$, $SD = 1.6$; 77.8% female) because it has been established that performance on speeded tasks tends to decline in early adulthood (Thompson et al., 2014). Participants were further screened for fluency in English and for normal or corrected vision and hearing. These qualifications were necessary to ensure full understanding of the instructions and the ability to detect the stimuli. Consent of participants were obtained before experimenting. The experiments were approved by the Institutional Review Board.

Measurements

Big Five Aspects Scale.

The BFAS an open-source personality assessment, consisting of 100 items. It measures the Big Five domains as well as ten lower-order aspects, two aspects per domain. See Table 3.2 to view the domains and aspects, as well as the descriptive statistics and reliability. Items are measured using a 5-point Likert scale (1 = Disagree – 5 = Agree). A full list of the items can be found on https://ipip.ori.org/BFASKeys.htm.

International Cognitive Ability Resource 16-item Sample Test.

The ICAR-16 is the short-form version of the ICAR, an assessment tool with 16 items from the full public-domain ICAR (Condon & Revelle, 2014). The ICAR consists of four subtests: letter and number sequences, matrix reasoning, 3D rotation, and verbal reasoning. The descriptive statistics and reliability of the ICAR-16 in the current sample is shown in Table 3.3.

Procedure

Stimuli was presented on an IBM-compatible computer running E-prime software. For the number task, the stimulus was a number from 1 through 9, excluding 5. Participants were asked to determine if the stimulus was less than or greater than the target value of 5 as quickly and as accurately as possible. Participants responses were made via computer keyboard. They were instructed to press the correct key—Q if the stimulus was less than the target and W if the stimulus was greater—as quickly as possible while still being highly accurate. For the tone task, the participants were presented with two audio tones sequentially. The first tone was a target tone of 660 Hz. The second stimulus tone consisted of eight total frequencies, four of which were below the target and four of which were above. They ranged from 440 Hz to 880 Hz, excluding the target tone. (See Table 3.4 for distributional characteristics of reaction time tasks and moments.) These decisional manipulations were labelled as distance. Distances were coded depending on their “distance” from the target value such that there were four levels of distance (hardest, hard, easy, easiest). Lower distance resulted in slower responses.

Similarly, both the numbers and tones were also perceptually manipulated. There were four total levels of perceptual contrast. In the numbers task, the opacity of the number against background was manipulated. In the tone task, the volume of the tone was manipulated. Lower Contrast also resulted in slower responses. A total combination of 16 conditions of distance and contrast were presented to the participant, randomized and counterbalanced. Participants first practiced in 30 trials before being tested in three blocks of 50 trials.

Analyses

All analyses were run in R (R Core Team, 2020). ANOVA and ANCOVA were conducted using the ezANOVA function of the EZ (v4.4-0) package (Lawrence, 2016). Confidence intervals testing for differences between dependent correlations were calculated with R's cocor package (Diedenhofen & Musch, 2015), and partial correlations with the ppcor package (Kim, 2015).

A participant's trial was dropped if its time was below 100 ms or more than 5 SDs from that participant's mean reaction time. Participants with too few entries per condition were also dropped from the final analysis.

The associations between intelligence and the BFAS domain were tested via correlational analysis as well as were the associations between reaction and the BFAS domains. Although it was only expected there would be a significant negative correlation with the Openness/Intellect domain and Intellect aspect, associations between reaction time and all domains/aspects and were tested. The domains and aspects were further tested if they correlated with the standard deviation of reaction time and accuracy. For each participant, standard deviation was initially calculated separately for each of the 16 levels distance and contrast. The average standard deviation across the 16 levels was then taken as the participant's overall standard deviation. It was expected that only the Intellect domain would be significantly correlated with standard deviation and accuracy.

To compare the relative strength of a correlation to another, Zou's (2007) method for computing confidence intervals for the difference between correlations was employed. When the intervals contain zero, there is no evidence to suggest that the correlations are significantly different. This method can account for dependence between correlations as well when the correlations are overlapping. Dependence occurs when the correlations are calculated in the same sample, and overlapping correlations are those that have one variable in common.

If Openness is related to the ability to perceive the stimulus, as suggested by the CB5T, then it should have an interactive effect with contrast since contrast affects perception of the stimulus. Conversely, Intellect, which relates to the detection of logical patterns, should have an interactive effect with distance since distance is a manipulation of the meaning of the stimulus. To this end, an analysis of covariance (ANCOVA) was used with Openness and Intellect, in separate analyses, as continuous between-subjects covariates and with distance and contrast as within-subject factors. It is anticipated that there is a significant interaction between Intellect and distance. And only if Openness correlates with mean reaction time, then is it proposed that Openness has an interactive effect with contrast on mean reaction time and an additive effect with distance.

Given the large number of analyses that were conducted, there was an increased likelihood that significant correlations would arise by chance alone. To correct for this, the significance threshold was lowered from the conventional $p = .05$ to $p = .005$. This lowered threshold has been shown to significantly decrease the rate of false positives even if other experimental, procedural, and reporting problems persist (Benjamin et al., 2018).

Results

Correlational Analyses

The results of the correlational analysis of the BFAS and intelligence are shown in Table 3.5. Main hypothesis 1 ("Openness/Intellect is positively correlated with cognitive ability; only Intellect is positively correlated with cognitive ability") was supported. The correlation of intelligence and Openness/Intellect was $r = .14$, $p =. 002$. The correlation of intelligence and Intellect was $r = .24$, $p < .001$. Openness and intelligence were not significantly correlated ($r = -.01$, $p = .863$). No other domain or aspect correlated with intelligence.

Similar results were observed for the correlational analysis of the BFAS and reaction time for both the number and tone tasks, meaning that main hypothesis 2 ("Openness/Intellect is negatively correlated with mean reaction time; only Intellect is negatively correlated with mean reaction time") was also supported (see Table 3.6 and Table 3.7). In the number task: mean reaction time and Openness/Intellect were correlated at $r = -.13$, $p = .003$; mean reaction time and Intellect were $r = -.18$, $p < .001$; and Openness was not significantly correlated to mean reaction time ($r = -.04$, $p = .393$). In the tone task: the correlation of mean reaction time and Openness/Intellect was $r = -.16$, $p = .001$; mean reaction time and Intellect was $r = -.21$, $p < .001$; mean reaction time and Openness was $r = -.05$, $p = .321$. The other domains and aspects did not associate with mean reaction time for either task.

Main hypothesis 3 ("Intellect is negatively correlated to standard deviation and positively correlated accuracy") was partially supported (see Table 3.6 and Table 3.7). Intellect was negatively correlated with standard deviation in the number task (r = -.16, p = .001) and in the tone task (r = -.19, p < .001). And while Intellect did positively correlate with accuracy in the tone task (r = .16, p < .001), it was not significantly correlated with accuracy in the number task (r = -.07, p = .128).

Analysis of Variance and Covariance

First, ANOVAs were run to determine whether distance and contrast had the intended effect on participants' mean reaction time. In the number task, both distance and contrast had a significant main effect ($F_{3,1425}$ = 368.1, p < .001; $F_{3,1425}$ = 835.5, p < .001). Likewise, significant main effects were found for distance and contrast in the tone task ($F_{3,1425}$ = 22.18, p < .001; $F_{3,1425}$ = 350.6, p < .001). (See Table 3.8 and Table 3.9 for details.) In the number task, increasing the distance or the contrast led to faster reaction times. Similar patterns of mean reaction times were observed for the levels of distance and contrast in the tone task. (See Table 3.8 for means and standard deviations.) Altogether, these results suggested that decreased distance or contrast did indeed increase the difficulty of the tasks.

Having established the main effects of distance and contrast, an ANCOVA was run to test main hypothesis 4 ("Intellect has an interactive effect with distance on mean reaction time and an additive effect with contrast"). A participant who was missing valid data for one cell mean was removed for the ANCOVAs (N = 476). Mean reaction time was the dependent variable, distance or contrast the within-subject factor, and Intellect the between-subjects covariate. Main hypothesis 4 was not supported by results of the number task, but it was supported by the tone task. In the number task, Intellect and distance did not have a significant interactive effect ($F_{3,1422} = 2.8$, $p = .050$), nor did Intellect and contrast ($F_{3,1422} = 3.6$, $p = .772$). In the tone task, there was a significant interaction between Intellect and distance ($F_{3,1422} = 7.2$, $p < .005$), but not Intellect and contrast ($F_{3,1422} = 2.1$, $p = .102$). See Table 3.8 and Table 3.9.

Exploring the Ancillary Hypotheses

While the ancillary hypotheses were not anticipated to hold given the evidence found in support of main hypothesis 1, the ancillary hypotheses were explored. Openness did not correlate with the standard deviation of reaction time or accuracy on either the number or tone task (see Table 3.6 and Table 3.7). Openness did not have a significant interaction with either manipulation, regardless of the task (see Table 3.8 and Table 3.9 for *F* ratios and *p*-values).

Comparing the Correlations of Intelligence to Intellect and Intelligence to Openness

Although it was established that Intellect correlates with intelligence, while Openness does not, these correlations were empirically compared to further establish that Intellect's association with intelligence is stronger than that of Openness. Using Zou's (2007) method, it was found that the difference between the two correlations had a 99.5% confidence interval of [.10, .40]. Since the interval did not contain 0, it indicated that the correlation between intelligence and Intellect is significantly greater than the correlation between intelligence and Openness.

Partial Correlation of Intellect and Reaction Time

To test if the relationship between Intellect and reaction time could actually be attributed to each variable's association with intelligence, partial correlations were conducted. In the number task, after controlling for intelligence, the correlation between mean reaction time and Intellect was no longer significant (r = -.10, p = .033). However, the correlation remained significant in the tone task (r = -.16, p = .001). Together, both results suggest that Intellect has a unique relationship with reaction time, although that relationship may not be substantial.

Discussion

This study examined the relationships between intelligence, reaction time, and Openness/Intellect. If the delineation of this domain into the Openness and Intellect aspects are valid, the results should show that Intellect associates with intelligence and reaction time, while Openness does not. Since Intellect has been described as self-reported intelligence, it was expected that Intellect would associate with reaction time in the same or similar manner as intelligence does. Openness was not anticipated to associate with reaction time. If these expectations were met, the results would support the discriminant validity of this Openness/Intellect hierarchy. To this end, two reaction time paradigms were used, one involving a number comparison task and the other a tone comparison.

First, it was anticipated that Openness/Intellect would positively correlate with intelligence; this finding was supported. And as expected, it was primarily the Intellect aspect within this domain that drove the association. It was further found that Intellect correlated with the mean reaction time as well as standard deviation and accuracy, parameters that reflect information processing at the decisional stage (in the tone task). Altogether, these results suggest that intelligence and Intellect are strongly related. Intellect has been described as the perception of one's intelligence, and that description does not appear to be too far from the truth. Studies have found that the correlation of Intellect with direct self-ratings of intelligence to be about .25 to .35 (DeYoung et al., 2014). Individual's self-assessment of their IQ also tend to be more accurate when asked to report on specific abilities related to intelligence—such as verbal, mathematical, or spatial—rather that general intelligence (Ackerman et al., 2002). Other people's perception of a person's intelligence may be accurate as well. Teachers, who generally tend to be aware of their student's cognitive abilities, are able to predict students' IQ, with correlations ranging from .45 - .85 (DeYoung, 2011). It would be interesting to find if peers and family members are similarly able to predict others' IQ.

The results of this study did not replicate that of Rammsayer et al. (2014), who found that Extraversion was negatively correlated with mean reaction time. Here, Extraversion did not significantly correlate with mean reaction time—nor standard deviation and accuracy—suggesting that Extraversion does not have a substantial relationship with reaction time as proposed by Rammsayer et al. However, it was found that the Orderliness aspect of the Conscientiousness domain significantly correlated with accuracy in the number task ($r = .13$, $p = .004$), which was unanticipated. Orderliness is marked by carefulness, punctuality, and neatness (whereas Industriousness, the other aspect of Conscientiousness, captures perseverance and self-discipline). Perhaps individuals with higher levels of Orderliness are more careful to come to a correct decision in a two-choice reaction time task. Since Orderliness does not positively correlate with mean reaction time, however, this possibility seems unlikely. And furthermore, this correlation between Orderliness and accuracy was not significant in the tone task. Despite the lowered significance threshold used in this study, this significant correlation in the number task is likely a false positive.

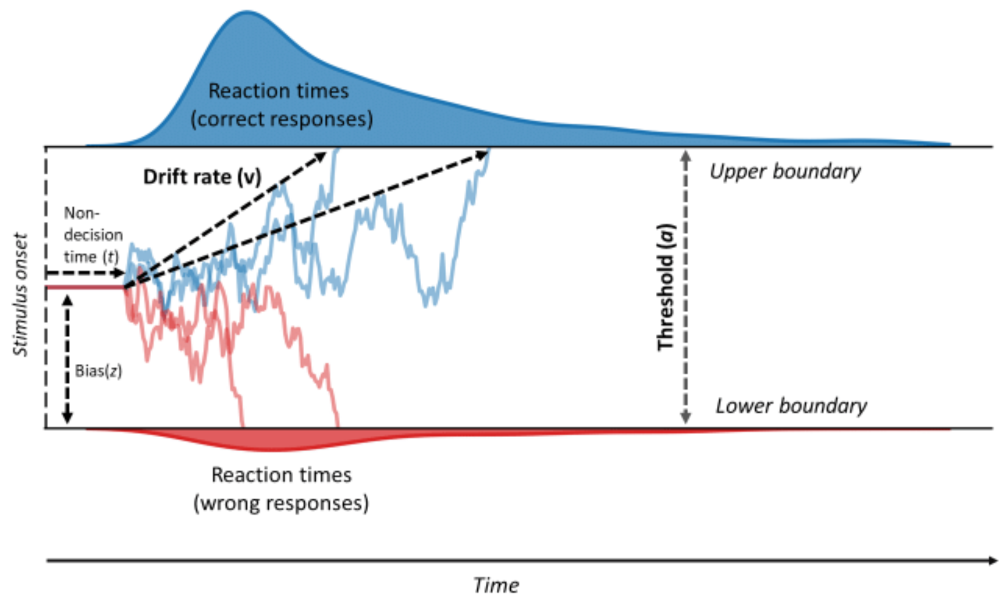
Based on the CB5T, it was expected that Intellect would confer an advantage in the reaction time tasks, such that individuals with higher Intellect would have faster reaction times on average across all levels of distance. The results of the number task did not support this hypothesis, but the tone task did. It is not clear why the interaction between Intellect and distance was only significant in the tone task. Likewise, it is unknown why there was no significant correlation of Intellect with accuracy, and no significant correlation between Intellect and mean reaction time once intelligence was controlled for, but only in the number task. In Willoughby and Lee (2021), the study from which the reaction time paradigms used here originate, ANCOVAs were run with intelligence as the between-subjects covariate predicting mean reaction time. Using a sample of $N = 773$, they observed that intelligence significantly interacted with distance on both tasks, with a larger effect size being observed in the number task. The difference in the results may be attributable to sample size or be an example of the way in which Intellect is distinct from intelligence. It has been proposed that Intellect separates from intelligence in part by capturing the tendency or willingness to more effortfully engage with abstract information (Smillie et al., 2016).

It was also anticipated that Openness would not associate with reaction time; although it has been found to associate with verbal ability and is correlated with Intellect, Openness is considered to be a distinct construct. This study generally supports this assertion. Unlike Intellect, Openness did not significantly associate with intelligence, mean reaction time, standard deviation, or accuracy on any task; nor did Openness significantly interact with distance. If Openness were not its own distinguishable subfactor within the Openness/Intellect domain, such a pattern of results would not be observed. Openness and Intellect has been shown to diverge in many other respects as well. These aspects differentially associate with or predict other cognitive abilities (such as working memory), achievements in the arts vs sciences, academic performance, job performance, political orientation, and mental health (Hirsh et al., 2010; DeYoung et al., 2014; Kaufman et al., 2016; Smillie et al., 2016).

Conclusion

Overall, this study provides further support for the construct validity of the Openness and Intellect aspects. Evidence from this study generally indicates that reaction time associates with Intellect, but not Openness. One of the major criticisms Hans Eysenck had against the Big Five model of personality was its failure to be rooted in biology (Eysenck, 1991). He contended that an accurate model of personality must not only provide psychometric support, but show support that is based in genetics, neuroscience, or biology as a whole. Eysenck put forward that other models of personality, including his own three-domain model (Extraversion, Neuroticism, and Psychoticism), could explain variation in personality more parsimoniously while simultaneously offering testable theories on the biological mechanisms through which individual differences arise. In showing that reaction time is more related to Intellect than Openness, this study meets this criterion set forth by Eysenck. As reaction time is thought to provide an index of more fundamental mental processes, this study provides some evidence that the difference between Intellect and Openness is not an artifact of factor analysis, but rather is rooted at the cognitive and biological levels. Though these results cannot give a decisive conclusion on this issue, future research should continue to research the relationship between intelligence, reaction time and Openness/Intellect, along with its aspects and facets, to further investigate how this domain manifests cognitively and biologically—and to further examine the extent to which Intellect is more than just self-described intelligence.

Figure 3.1



Note. Illustration of the diffusion model. Reprinted from "Volition in prospective memory: Evidence against differences between free and fixed target events" by M.C. Vinding et al., 2021, p. 103175-103175. Copyright 2021 by Elsevier.

Table 3.1

BFAS Aspects Aligned with Facets of the NEO-PI-R and BFI-2

	BFAS (DeYoung et al., 2007)	NEO-PI-R (Costa & McCrae, 2008)	BFI-2 (C. J. Soto & John, 2017)
Domain	Openness/Intellect	Openness to Experience	Open-Mindedness
Subfactors	Openness	Aesthetics	Aesthetic Sensitivity
	Intellect	Ideas	Intellectual Curiosity

Note. Adapted from "The next Big Five Inventory (BFI-2): Developing and assessing a hierarchical model with 15 facets to enhance bandwidth, fidelity, and predictive power" by C.J. Soto and O.P. John, 2016, p. 117-143. Copyright 2016 by American Psychological Association.

Table 3.2

Descriptive Statistics and Reliability for the BFAS

Domains Aspects	*M*	*SD*	α	ω_h	ω_t
Openness/Intellect	3.70	.47	.76	.70	.83
Openness	3.77	.62	.83	.72	.87
Intellect	3.64	.55	.80	.62	.83
Extraversion	3.55	.56	.90	.60	.92
Assertiveness	3.38	.67	.86	.66	.89
Enthusiasm	3.72	.64	.86	.66	.89
Neuroticism	2.85	.65	.91	.66	.93
Volatility	3.02	.69	.85	.83	.88
Withdrawal	2.69	.76	.90	.75	.92
Agreeableness	4.06	.44	.87	.71	.89
Compassion	4.23	.50	.88	.85	.90
Politeness	3.89	.52	.75	.55	.79
Conscientiousness	3.53	.53	.87	.48	.90
Industriousness	3.32	.63	.84	.78	.86
Orderliness	3.74	.62	.83	.57	.87

Note. α = Cronbach's alpha. ω_h = omega hierarchical, ω_t = omega total. The means are on a 5-point scale.

Table 3.3

Descriptive Statistics and Reliability for the ICAR-16

M	*SD*	α	ω_h	ω_t
.62	.20	.81	.66	.83

Note. α = Cronbach's alpha. ω_h = omega hierarchical, ω_t = omega total. The ICAR-16 scores are scaled from 0 to 1.

Table 3.4

Distributional Characteristics of Reaction Time Tasks and Parameters Across Individuals

Task Moment	*M*	*SD*	Min	Max
Number Task				
RT *M*	534.2	78.0	386.8	876.2
RT *SD*	106.5	43.4	42.5	359.5
Accuracy	.981	.015	.928	1.00
Tone Task				
RT *M*	609.6	184.1	342.8	1908.2
RT *SD*	172.5	130.3	45.0	1180.5
Accuracy	.939	.057	.466	1.00

Note. RT stands for reaction time. Reaction time was measured in milliseconds. Accuracy is presented as a proportion.

Table 3.5

Correlations between the measures of the BFAS and ICAR-16

Domain Aspect	Intelligence *r*	99.5% CI Lower Limit	 Upper Limit
Openness/Intellect	**.14**	.01	.26
Openness	-.01	-.14	.12
Intellect	**.24**	.12	.36
Extraversion	-.08	-.21	.05
Assertiveness	-.03	-.16	.10
Enthusiasm	-.11	-.23	.02
Neuroticism	-.05	-.18	.08
Volatility	-.03	-.16	.09
Withdrawal	-.06	-.18	.07
Agreeableness	-.05	-.18	.07
Compassion	-.03	-.16	.10
Politeness	-.07	-.19	.06
Conscientiousness	-.06	-.18	.07
Industriousness	-.03	-.16	.10
Orderliness	-.04	-.09	.17

Note. Significant correlations ($p < .005$) are in bold.

Table 3.6

Correlations between the measures of the BFAS and RT Mean, Standard Deviation, and Accuracy of the Number Task

Domain Aspect	RT								
	M			*SD*			Accuracy		
	r	99.5% CI Lower Limit	99.5% CI Upper Limit	*r*	99.5% CI Lower Limit	99.5% CI Upper Limit	*r*	99.5% CI Lower Limit	99.5% CI Upper Limit
Openness/Intellect	**-.13**	-.26	-.01	**-.11**	-.24	.01	-.04	-.16	.09
Openness	-.04	-.17	.09	-.03	-.16	.09	-.01	-.12	.14
Intellect	**-.18**	-.30	-.06	**-.16**	-.28	-.03	-.07	-.20	.06
Extraversion	-.05	-.17	.08	-.03	-.16	.10	.06	-.07	.19
Assertiveness	-.06	-.18	.07	-.05	-.18	.08	.01	-.12	.14
Enthusiasm	-.02	-.15	.10	.00	-.13	.13	.09	-.03	.22
Neuroticism	.04	-.09	.17	.03	-.10	.16	.04	-.09	.17
Volatility	.01	-.11	.14	.01	-.12	.13	.03	-.10	.16
Withdrawal	.07	-.06	.20	.06	-.07	.18	.04	-.09	17
Agreeableness	.01	-.11	.14	.03	-.10	.15	.13	.00	.25
Compassion	-.02	-.14	.11	.00	-.13	.13	.12	-.01	.24
Politeness	.04	-.09	.17	.04	-.08	.17	.10	-.03	.23
Conscientiousness	-.07	-.20	.06	-.08	-.20	.05	.12	-.01	.25
Industriousness	-.08	-.21	.05	-.09	-.21	.04	.08	-.05	.20
Orderliness	-.04	-.16	.09	-.05	-.17	.08	**.13**	.002	.25

Note. Significant correlations ($p < .005$) are in bold.

Table 3.7

Correlations between the measures of the BFAS and RT Mean, Standard Deviation, and Accuracy of the Tone Task

Domain Aspect	RT Moments								
	M			*SD*			Accuracy		
	r	99.5% CI Lower Limit	99.5% CI Upper Limit	*r*	99.55% CI Lower Limit	99.5% CI Upper Limit	*r*	99.5% CI Lower Limit	99.5% CI Upper Limit
Openness/Intellect	**-.16**	-.28	-.03	**-.15**	-.27	-.02	.13	.00	.25
Openness	-.05	-.17	.08	-.05	-.17	.08	.05	-.08	.18
Intellect	**-.21**	-.33	-.09	**-.19**	-.32	-.07	**.16**	.03	.28
Extraversion	-.03	-.15	.10	-.04	-.17	.08	.09	-.03	.22
Assertiveness	-.03	-.15	.10	-.05	-.18	.08	.05	-.08	.18
Enthusiasm	-.02	-.15	.11	-.03	-.15	.10	.11	-.02	.24
Neuroticism	.03	-.10	-.16	.03	-.09	.16	-.01	-.13	.12
Volatility	-.01	.14	.12	-.02	-.15	.11	.01	-.12	.14
Withdrawal	.07	-.06	.20	.08	-.04	.21	-.02	-.15	.10
Agreeableness	.00	-.13	.13	.01	-.11	.14	.12	-.01	.25
Compassion	-.02	-.15	.11	-.02	-.14	.11	.13	.00	.26
Politeness	.02	-.11	.15	.04	-.09	.17	.08	-.05	.20
Conscientiousness	-.01	-.14	.12	-.02	-.15	.10	.07	-.05	.20
Industriousness	-.04	-.17	.09	-.08	-.20	.05	.06	-.07	.18
Orderliness	.03	-.10	.16	.04	-.09	.17	.07	-.06	.19

Note. Significant correlations ($p < .005$) are in bold

Table 3.8

ANOVA and ANCOVA for Manipulations, Intellect, and Openness on Mean Reaction Time in the Number Task

Analysis Type Effect	df_{Num}	df_{Den}	SS_{Num}	SS_{Den}	F	p
ANOVA						
Distance	3	1425	2408082	3107330	**368.1**	< .001
Contrast	3	1425	6006702	3414949	**835.5**	< .001
ANCOVA						
Intellect:Distance	3	1422	19845	3395093	2.8	.050
Intellect:Constrast	3	1422	2369	3104961	.4	.772
Openness:Distance	3	1422	947	3414002	1.3	.941
Openness:Contrast	3	1422	15244	3092087	2.3	.072

Note. Significant F statistics are in bold.

Table 3.9

ANOVA and ANCOVA for Manipulations, Intellect, and Openness on Mean Reaction Time in the Tone Task

Analysis Type Effect	df_{Num}	df_{Den}	SS_{Num}	SS_{Den}	F	p
ANOVA						
Distance	3	1425	24697857	33459473	**350.6**	< .001
Contrast	3	1425	480662	10295208	**22.2**	< .001
ANCOVA						
Intellect:Distance	3	1422	49895	32960521	**7.2**	< .001
Intellect:Constrast	3	1422	44793	10250415	2.1	.102
Openness:Distance	3	1422	6599	10288609	.3	.823
Openness:Contrast	3	1422	106282	33353191	1.5	.210

Note. Significant F statistics ($p < .005$) are in bold.

Conclusion

Together, these studies represent an expansion of the nomological net of personality psychology. Each study extended the nomological net by undertaking a more rigorous or comprehensive methodology. Using a genetically informative sample or biologically relevant variable, these studies also delved further into the biology underlying personality. Here I provide a recapitulation of these studies.

In Study 1, I investigated the development of personality over time. Although there exist a number of longitudinal studies of personality, the extrapolation of these studies is hamstrung by their limited number of assessments and overall duration of the study. And many of these studies do not include a genetically informative sample and tend to focus on the domain level of personality. Study 1 was not similarly bound by these limitations and examined the 11 primary scales of the MPQ in a sample of twins. Using behavior genetic methods, I estimated the magnitude of genetic and environmental influences on personality across four to seven waves of assessment that spanned over 30 years, as well as the extent to which these influences contribute to stability or change of personality over time. I found that the mean-level scores of traits related to Positive Affect generally did not change, whereas the scores of traits related to Constraint and Negative Affect did, in congruence with the maturity principle. In examining the etiology of personality stability and change, I found that both were influenced by genetic and nonshared environmental sources, with little influence from the shared environment. Heritability did change significantly across waves, but no clear pattern emerged, with heritability estimates generally ranging between 40% and 60%. Interestingly, for four traits (Social Potency, Social Closeness, Achievement, and Control), I discovered that the genetic sources included nonadditive genetic influence. In these traits, both dominance and nonshared environmental sources tended to contribute about equally to stability and change. Using a more rigorous methodology, this study generally reaffirmed the findings of the prevailing literature, while also detecting the presence of nonadditivity.

In Study 2, I examined the relationship between parenting and self-control, as well as aggression, across two waves of measurement in adolescence. While research into self-control holds that parenting is an important causal factor, the majority of this research bases this claim on study designs that do not use genetically informative samples—overlooking the possibility of genetic confounding. To test this idea, Study 2 employed a genetically sensitive design. Using a sample of nonadoptive and adoptive siblings, I examined the associations between self-control, as well as aggression, and parenting. Is there a causal relationship between self-control and parenting? Or can the relationship be attributed entirely to genetic confounding? Overall, there was evidence against a causal relationship: parenting did not have a longitudinal effect on parenting in either the adoptive or nonadoptive subsamples. However, there also was no evidence that self-control was at all heritable in late adolescence. Thus, while I did not find evidence in favor of a causal relationship, I simultaneously did not find that there was genetic confounding. This sample of participants may represent a unique group of individuals for whom there is no longitudinal relationship between self-control and parenting, and possibly individuals whose levels of self-control bear no resemblance to those of their family members. Although the underlying genetics of self-control were not fully expounded in Study 2, the study did affirm that self-control, like many other personality traits, is greatly influenced by the nonshared environment.

In Study 3, I explored the relationships among personality, intelligence, and reaction time. In particular, I investigated the structure of the Openness/Intellect domain from the Big Five Aspects Scale and how its aspects (Openness and Intellect) differentially relate to intelligence and to reaction time. Given the extensive literature showing the association between Intellect and intelligence, it was expected that Intellect would associate most strongly with intelligence and with reaction time, which is a well-established correlate of intelligence. This study further supported the construct validity of Intellect and Openness, as two related, but separable subfactors within their domain. If Intellect is distinct from Openness because it captures variance in intellectual pursuits, intellectual curiosity, and intelligence itself, Intellect should associate with external variables in a manner that resembles or replicates the patterns of associations that exist for intelligence. And indeed, the results broadly indicated that Intellect does relate to reaction time in many of the ways that intelligence does. The theory underlying the two-factor division of the Openness/Intellect domain was mostly validated by the results. This study provides evidence that Intellect and Openness are distinct subfactors that may arise from independent biological sources.

In summary, these studies expand the nomological net by measuring a twin sample over a long period of time, by using an adoptive sample to investigate the issue of genetic confounding, and by utilizing reaction time in a pioneering study. While the full substantiation of personality does require further work, particularly in our understanding of its genomic and neurobiological underpinnings, the research presented here shows that prevailing models of personality are not mere artifacts of factory analysis or simply a descriptive sketch of individual differences. Altogether, these studies take a path towards further establishing the validity of personality as a construct, as well as a path towards better understanding the psychology and biology of personality.

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Appendices

Appendix A: Supplementary Material for Study 1

Supplementary Table 1.1

Descriptive Statistics by Wave

Wave	*N*	Age *M* (*SD*)	Age Min.	Age Max.	Female%	MZ%	Scale
14	1,570	14.92 (.57)	13.57	17.02	73%	61%	PBYA
17	3,286	17.84 (.64)	16.55	20.34	53%	64%	MPQ
20	768	20.67 (.60)	19.45	22.72	80%	66%	MPQ
24	3,064	24.85 (.91)	22.63	29.30	55%	63%	MPQ
29	2,436	29.42 (.65)	28.16	33.14	53%	65%	MPQ
35	858	34.62 (1.30)	32.73	39.91	56%	61%	PBYA
42	1,069	40.91 (2.51)	35.67	47.73	57%	65%	PBYA[a]

[a]Traditionalism was included in this wave

Note. PBYA stands for Personality Booklet Youth Abbreviated, and MPQ for the Minnesota Personality Questionnaire.

Supplementary Table 1.2

Results of Testing Sex Differences

Scale	Model	Parameters	*df*	AIC
Well-Being	Full	72	52404	239,193
	Constrained	42	52434	239,355
Social Potency	Full	54	33038	152,847
	Constrained	33	152988	152,989
Achievement	Full	54	32990	154,311
	Constrained	33	33011	154,366
Social Closeness	Full	54	33098	155,777
	Constrained	33	33119	155,860
Stress Reaction	Full	72	52436	255,592
	Constrained	42	52466	255,762
Alienation	Full	72	52460	247,279
	Constrained	42	52490	247,383
Aggression	Full	72	52464	237,260
	Constrained	42	52494	237,832
Control	Full	72	52436	237,613
	Constrained	42	52466	237,811
Harm Avoidance	Full	72	52380	252,568

	Constrained	42	52410	252,709
Traditionalism	Full	60	37048	158,990
	Constrained	36	37072	1591,00
Absorption	Full	54	32982	161,455
	Constrained	33	33003	161,479

Supplementary Table 1.3

Results of Comparing Nested ACE and ADE Models

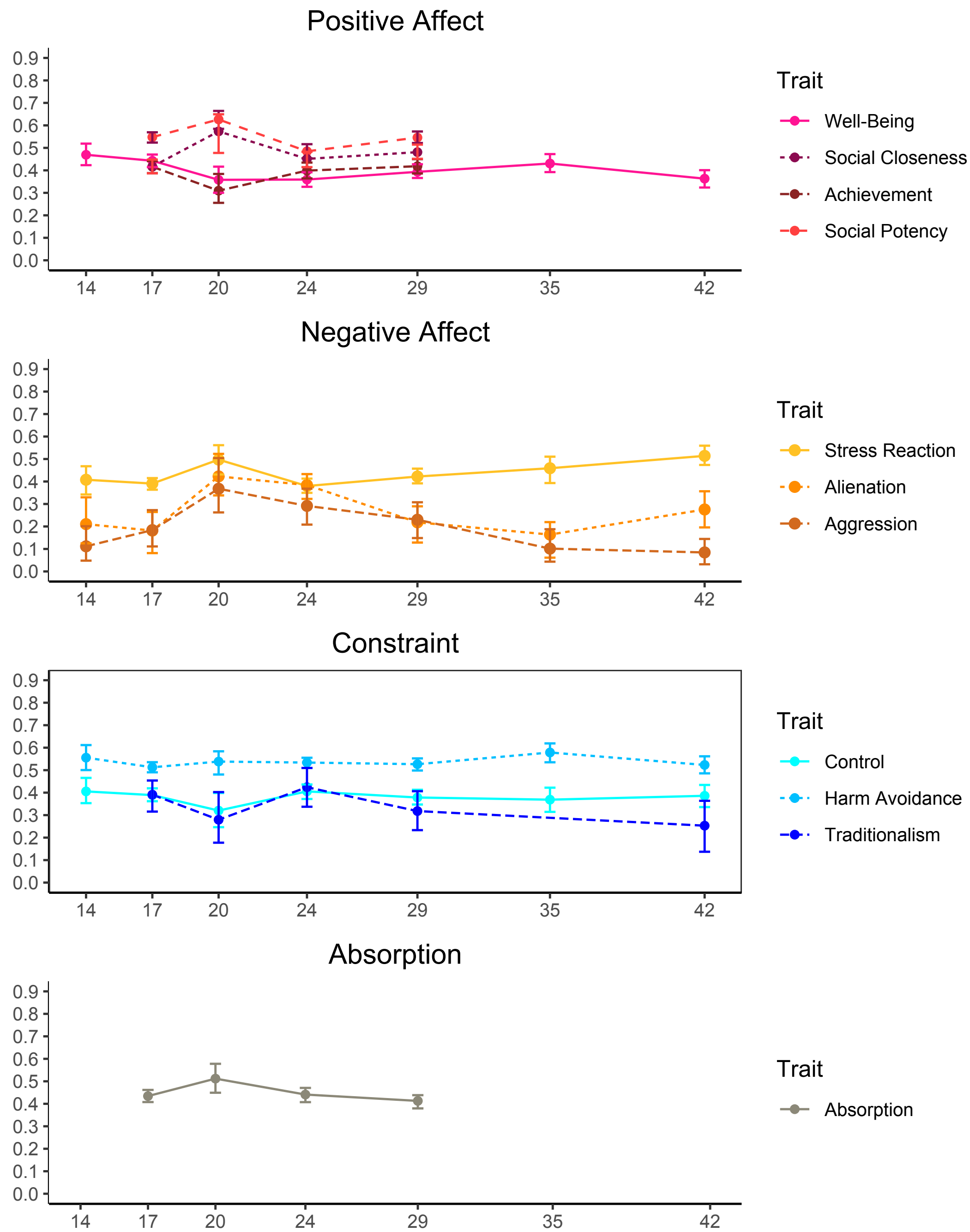
	Model	Parameters	*df*	AIC
Well-Being	ACE	72	52404	239,193
	ADE	72	52404	239,174
	AE	52	52424	**239,170**
	E	32	53444	241,588
Social Potency	ACE	54	33038	152,847
	ADE	54	33038	**152,803**
	AE	40	33952	152,825
	E	26	33066	154,715
Achievement	ACE	54	32990	220,399
	ADE	54	32990	**220,347**
	AE	40	33004	220,373
	E	26	33018	221,897
Social Closeness	ACE	54	33098	155,777
	ADE	54	33098	**155,709**
	AE	40	33112	155,750
	E	26	33126	157,209
Stress Reaction	ACE	72	52436	255,592
	ADE	72	52436	255,587
	AE	52	52466	**255,564**
	E	32	52486	257,793
Alienation	**ACE**	72	52460	**247,279**

	ADE	72	52460	247,319
	AE	52	52490	247,286
	E	32	52510	250,763
Aggression	**ACE**	72	52464	**237,260**
	ADE	72	52464	237,330
	AE	52	52494	237,314
	E	32	53514	240,798
Control	ACE	72	52436	237,613
	ADE	72	52436	**237,557**
	AE	52	52456	237,589
	E	32	52476	238,986
Harm Avoidance	ACE	72	52380	252,568
	ADE	52	52380	252,551
	AE	52	52400	**252,542**
	E	32	52420	255,779
Traditionalism	**ACE**	60	37048	**158,990**
	ADE	60	37048	159,033
	AE	44	37064	159,100
	E	28	37080	162,598
Absorption	ACE	54	32982	161,455
	ADE	54	32982	161,445
	AE	40	32996	**161,430**
	E	26	33010	163,206

Note. The bolded text represents the best-fitting model with the lowest AIC.

Supplementary Figure 1.1

Estimate of Heritability at Each Available Wave in Men



Note. The x-axis is the wave. The y-axis is the estimated heritability, which is in the broad sense if a dominance component was estimated (Social Closeness, Achievement, Social Potency, and Control). Bars indicate the 95% confidence interval.

Supplementary Table 1.4

Comparison of Full Cholesky and Models in Which Heritability was Constrained in Females

Scale	Model	Parameters	*df*	AIC
Well-Being	Full	48	27944	**184480.6**
	Constrained	48	27949	184494.7
Social Closeness	Full	34	17458	**117511.1**
	Constrained	34	17461	117517.7
Achievement	Full	34	17410	**116082.1**
	Constrained	34	17413	116084.2
Social Potency	Full	34	17426	**116646.9**
	Constrained	34	17429	116648.2
Stress Reaction	Full	63	30421	**209194.3**
	Constrained	63	30427	209231.7
Alienation	Full	91	30405	**202822.6**
	Constrained	91	30411	202837.8
Aggression	Full	91	30401	**194061.2**
	Constrained	91	30408	194077.2
Control	Full	91	30381	**198229.4**
	Constrained	91	30388	211821.0
Harm Avoidance	Full	48	27932	**189126.8**
	Constrained	48	27937	189136.0

Traditionalism	Full	34	19614	**122635.0**
	Constrained	34	19617	122641.9
Absorption	Full	24	17404	**120205.1**
	Constrained	24	17407	120212.0

Note. The bolded text represents the best-fitting model with the lowest AIC.

Supplementary Table 1.5

Comparison of Full Cholesky and Models in Which Heritability was Constrained in Males

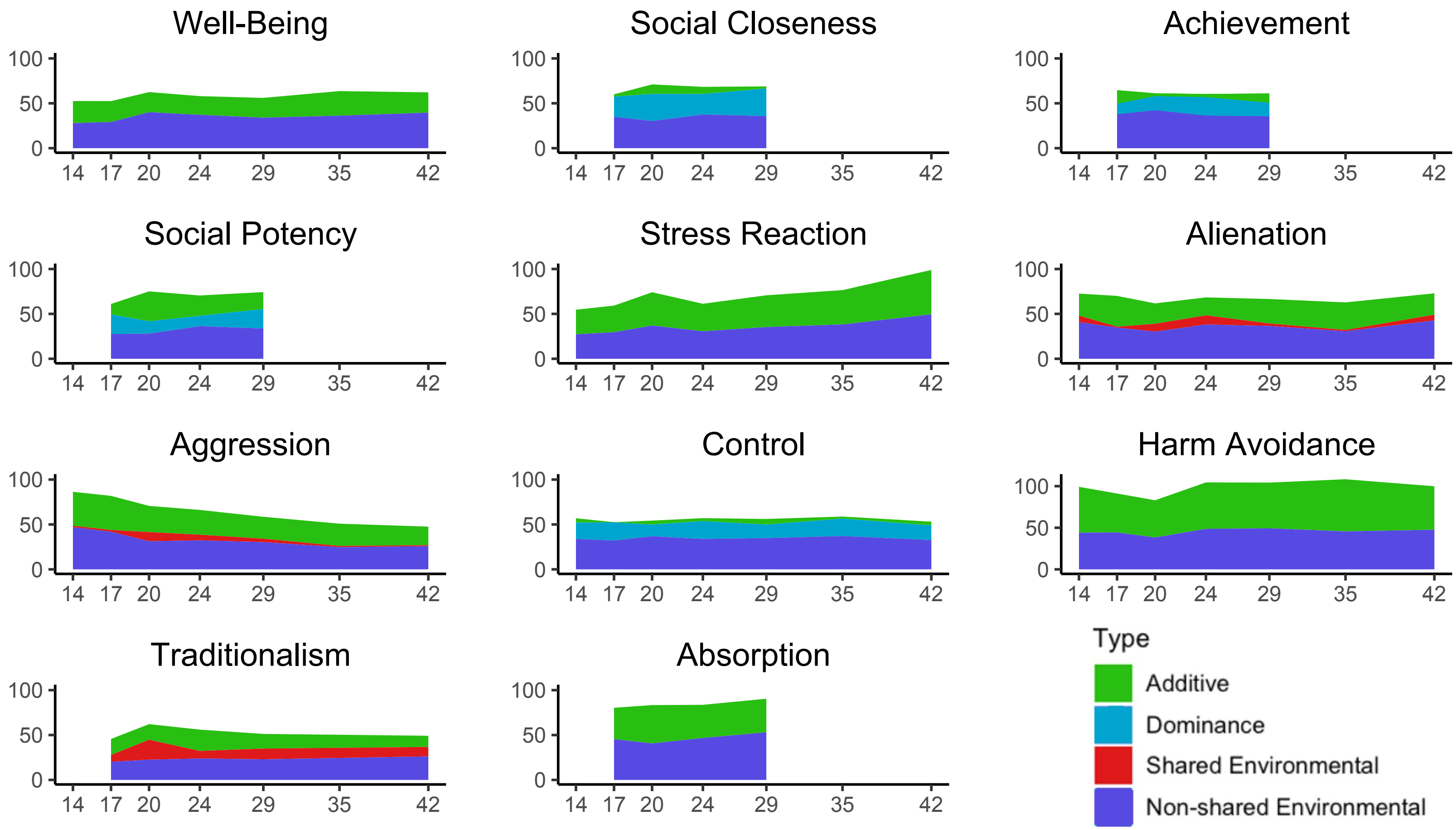
Scale	Model	Parameters	*df*	AIC
Well-Being	Full	63	21957	**143021.7**
	Constrained	63	21963	143042.1
Social Closeness	Full	34	15626	**104445.1**
	Constrained	34	15629	104446.1
Achievement	Full	34	15566	**104112.8**
	Constrained	34	15569	104117.0
Social Potency	Full	34	15598	**102275.6**
	Constrained	34	15561	102284.7
Stress Reaction	Full	63	21961	**149695.6**
	Constrained	63	21967	149719.7
Alienation	Full	91	21945	**146892.5**
	Constrained	91	21951	146911.4
Aggression	Full	91	21953	**145637.5**
	Constrained	91	21959	145640.5
Control	Full	91	21945	**142340.4**
	Constrained	91	21951	142343.8
Harm Avoidance	Full	63	21933	**150696.1**
	Constrained	63	21939	150704.4

Traditionalism	Full	50	17282	**109219.8**
	Constrained	50	17286	109229.3
Absorption	Full	24	15584	**107498.1**
	Constrained	24	15597	107503.6

Note. The bolded text represents the best-fitting model with the lowest AIC.

Supplementary Figure 1.2

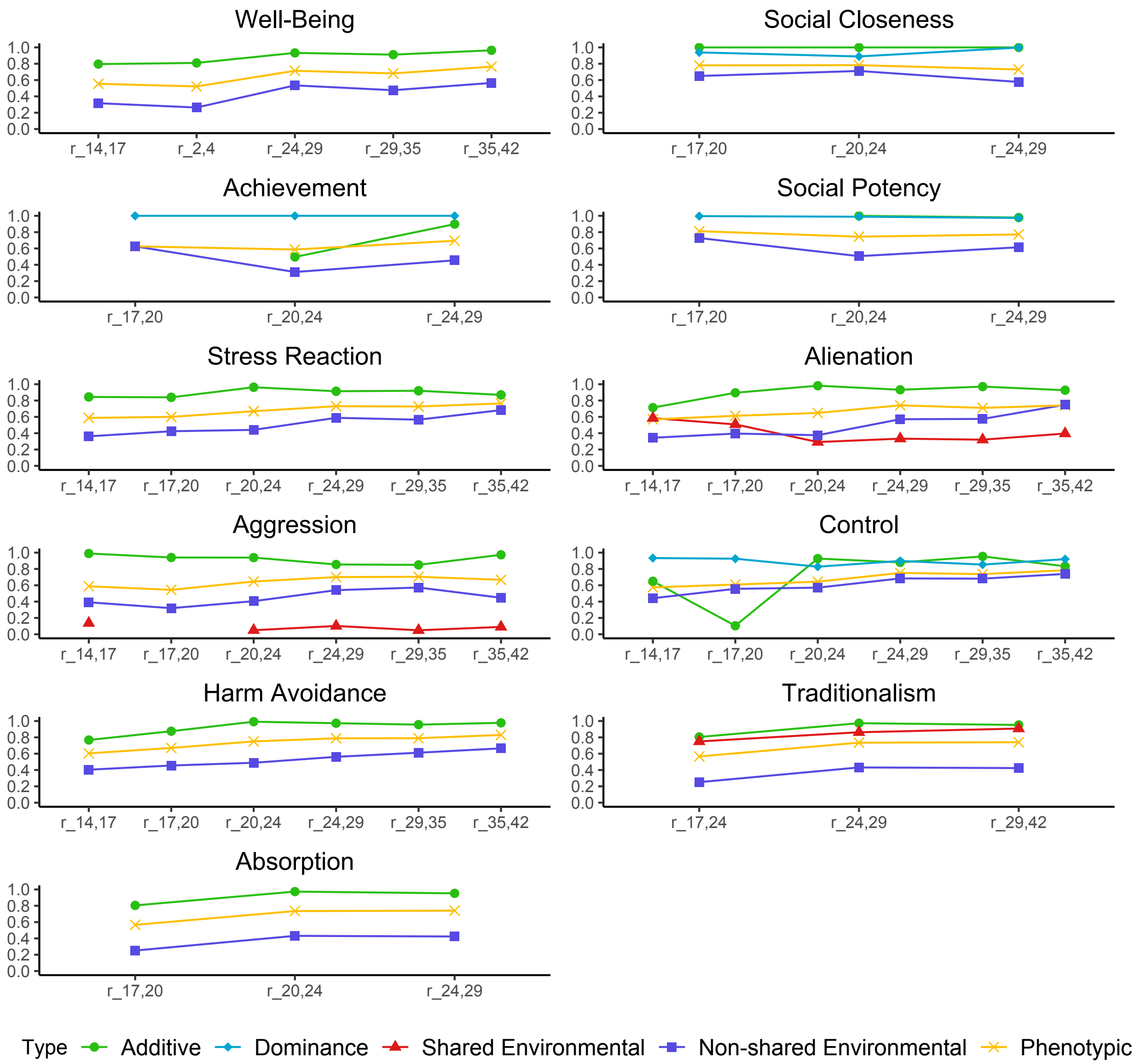
Stacked Unstandardized Variance Components in Males



Note. Stacked unstandardized variance components of additive genetic, dominance, shared and non-shared environmental effects across waves based on the best fitting models.

Supplementary Figure 1.3

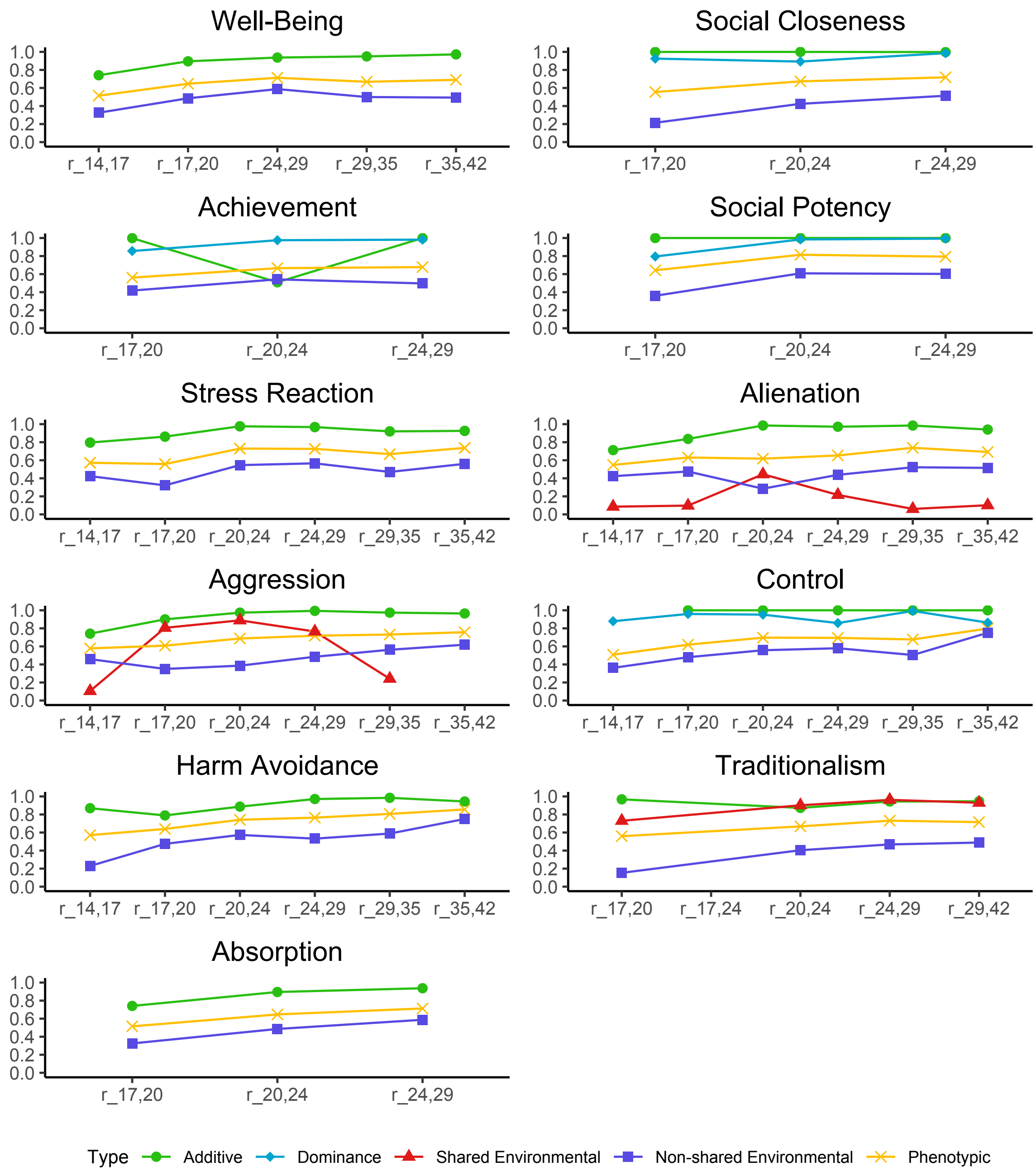
Phenotypic, Genetic, Dominance, and Environmental Correlations between Subsequent Waves in Females



Note. The x-axis is the correlation between subsequent waves. The y-axis is the correlation coefficient. The 95% confidence intervals can be found in the supplement.

Supplementary Figure 1.4

Phenotypic, Genetic, Dominance, and Environmental Correlations between Subsequent Waves in Males



Note. The x-axis is the correlation between subsequent waves. The y-axis is the correlation coefficient. The 95% confidence intervals can be found in the supplement.

Appendix B: Supplementary Material for Study 2

Supplementary Table 2.1

Attrition Analysis of Sample 2 at Wave 2

Variable	χ^2	*t*	*df*	*p*	Cohen's *d* [95% CI]
Categorical					
Sex	.60	-	1	.439	-
Race	.25	-	3	.969	-
Adoptive Status	.17	-	1	.680	-
Sibship Type	.18	-	1	.673	-
Continuous					
Self-Control	-	-1.9	1211	.059	-.19 [-.39, .01]
Aggression	-	1.5	1120	.123	.16 [-.04, .36]
Parenting	-	.05	1157	.961	.01 [-.21, .22]
SES	-	.34	134	.733	.03 [-.17, .23]

Note. For categorical variables, a chi-squared (χ^2) test for proportions was conducted to determine if certain participants were less likely to participate in wave 2, using wave 1 as the baseline. For continuous variables, Welch two sample *t* tests were conducted to compare the scores (as measured at wave 1) of participants who returned at wave 2 to those who dropped out. Standardized mean differences (*d*) are also reported. Socioeconomic status (SES) was calculated as an overall *Z*-score based on parents' level of education, occupation, and family income.

Supplementary Table 2.2

Correlations Among Self-Control, Aggression, and Parenting at Waves 1 and 2 Regardless of Adoptive Status

Variable	1	2	3	4	5
1. Self-Control Wave 1					
2. Self-Control Wave 2	**.44** [.33, .54] *N* = 999				
3. Aggression Wave 1	**-.46** [-.54, -.36] *N* = 1212	**-.19** [-.31, -.07] *N* = 998			
4. Aggression Wave 2	**-.26** [-.37, -.14] *N* = 1001	**-.37** [-.48, -.27] *N* = 999	**.55** [.45, .63] *N* = 1000		
5. Parenting Wave 1	.11 [.00, .21] *N* = 1141	.08 [-.01, .20] *N* = 944	-.08 [-.19 .07] *N* = 1140	-.04 [-.16, .07] *N* = 946	
6. Parenting Wave 2	.05 [-.06, .16] *N* = 1144	**.14** [.03, .25] *N* = 934	.03 [-.09, .15] *N* = 1043	-.08 [-.22, .06] *N* = 936	**.45** [.34, 55] *N* = 1005

Note. Significant correlational values are in bold. Brackets show 95% confidence intervals (calculated using clustered bootstrapping).

Supplementary Table 2.3

Correlations Among Self-Control, Aggression, and Parenting at Waves 1 and 2 in the Nonadoptive Subsample

Variable	1	2	3	4	5
1. Self-Control Wave 1					
2. Self-Control Wave 2	**.44** [.36, .51] *N* = 444				
3. Aggression Wave 1	**-.46** [-.52, -.39] *N* = 533	**-.19** [-.27, -.10] *N* = 444			
4. Aggression Wave 2	**-.26** [-.34, -.17] *N* = 444	**-.37** [-.45, -.29] *N* = 444	**.55** [.48, .61] *N* = 444		
5. Parenting Wave 1	**.11** [.02, .19] *N* = 502	.08 [-.01, .18] *N* = 425	-.08 [-.16 .01] *N* = 502	-.04 [-.14, .05] *N* = 425	
6. Parenting Wave 2	.05 [-.04, 14] *N* = 452	**.14** [.05, .24] *N* = 414	.03 [-.07, .12] *N* = 452	-.08 [-.17, 02] *N* = 414	**.45** [.37, 52] *N* = 439

Note. Significant correlational values are in bold. Brackets show 95% confidence intervals (calculated using clustered bootstrapping).

Supplementary Table 2.4

Correlations Among Self-Control, Aggression, and Parenting at Waves 1 and 2 in the Adoptive Subsample

Variable	1	2	3	4	5
1. Self-Control Wave 1					
2. Self-Control Wave 2	**.64** [.58, .70] *N* = 555				
3. Aggression Wave 1	**-.45** [-.53, -.38] *N* = 679	**-.39** [-.48, -.31] *N* = 554			
4. Aggression Wave 2	**-.34** [-.43, -.24] *N* = 557	**-.47** [-.55, -.38] *N* = 555	**.61** [.53, .67] *N* = 556		
5. Parenting Wave 1	.08 [-.01, .18] *N* = 639	.02 [-.09, .12] *N* = 519	**-.14** [-.25, -.02] *N* = 638	-.07 [-.19, .02] *N* = 521	
6. Parenting Wave 2	.11 [.00, .21] *N* = 592	.07 [-.03, .16] *N* = 520	**-.11** [-.21, -.01] *N* = 591	-.10 [-.18, -.01] *N* = 522	**.44** [.34, .52] *N* = 566

Note. Significant correlational values are in bold. Brackets show 95% confidence intervals (calculated using clustered bootstrapping).

Supplementary Table 2.5

Correlation of Sibling Pairs' Self-Control and Aggression by Pair's Adoptive Status

Variable	Wave 1			Wave 2		
	All	Nonadoptive	Adoptive	All	Nonadoptive	Adoptive
Self-Control	.06 [-.02, .14] *N* = 598	**.16** [.02, .29] *N* = 203	.02 [-.08, .12] *N* = 395	**-.12** [-.21 -.03] *N* = 465	-.13 [-.28, .02] *N* = 164	-.11 [-.22, .01] *N* = 288
Aggression	**.19** [.12, .27] *N* = 601	**.34** [.21, .46] *N* = 203	**.12** [.02 .21] *N* = 394	**.19** [.10, .27] *N* = 468	**.30** [.15, .43] *N* = 164	**.12** [.005 .23] *N* = 290

Note. Significant ($p < .05$) correlational values are in bold. Brackets show 95% confidence intervals (calculated using clustered bootstrapping). *N* represents the number of sibling pairs.