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# Broad and narrow environmental and genetic sources of personality differences: An extended twin family study

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## Abstract

**Objective:** Several personality theories distinguish between rather genetically rooted, universal dispositional traits (DTs) and rather environmentally shaped, more contextualized characteristic adaptations (CAs). However, no study so far has compared different measures of theoretically postulated DTs and CAs regarding their environmental and genetic components while considering differences in measurement abstraction and reliability. This study aims to bridge this gap by testing the assumed differences in the sensitivity to environmental influences based on representative sets of DTs (Big Five and HEXACO domains and facets) and CAs (goals, interests, value priorities, religiousness, and self-schemas).

**Method:** Using intra-class correlations and running extended twin family and spouses-of-twins model analyses, we analyzed a large data set ( $N = 1967$ ) encompassing 636 twin pairs, 787 parent-offspring dyads, and 325 spouses/partners.

**Results:** Findings consistently support lower environmentality of DTs compared to CAs. On average, more than half of reliable variance in DTs was genetic, whereas the reverse was found for CAs. Larger environmental components in CAs were primarily attributable to larger individual-specific effects (beyond error of measurement) and factors shared by spouses.

**Conclusions:** Findings are discussed against the background of the definitional distinction between DTs and CAs and the value of extended twin family data.

## KEYWORDS

characteristic adaptations, dispositional traits, environmentality, heritability, personality, twin family study

## 1 | INTRODUCTION

Several theories typically distinguish between rather biologically rooted and rather environmentally shaped differences in personality characteristics, such as constitutional versus environmental-mold traits (Cattell, 1965)

or universal dispositional traits (DTs) versus more contextualized characteristic adaptations (CAs; McAdams & Pals, 2006). Despite some evidence for variation in genetic and environmental components between DTs (e.g., Big Five trait domains) and CAs (e.g., goals, interests, virtues, values, and self-schemas), the differences between

them have been found to be unsystematic and inconsistent across measures and studies (Henry & Möttus, 2020; Kandler et al., 2014; Nguyen et al., 2021). Most of these studies that distinguished environmental from genetic components are limited to the classical twin design. Indeed, no study so far—to our knowledge—has investigated different measures of theoretically postulated DTs and CAs at different levels of abstraction (i.e., broader dimensions versus narrower facets) and compared them regarding their environmental and genetic components in one and the same sample.

The current study aims to bridge this gap in both conceptual and methodological respects. Conceptually, we differentiate basic DTs and more contextualized CAs as two classes of personality characteristics based on prominent theories. This theoretical foundation allows us to compare them regarding the assumed differences in their sensitivity to environmental influences. Methodologically, we use data from an extended twin family study across generations (including twins plus their parents, offspring, and spouses) to overcome the limits of the classical twin design. In doing so, we distinguish different broad and narrow environmental sources from genetic contributions to variance in DTs and CAs, taking the psychometric quality of DT and CA measures as well as differences in the abstraction level of their measurement into account.

## 1.1 | Conceptual distinctions between traits and adaptations

The DT–CA differentiation is common to several prominent personality theories, such as the Five-Factor Theory (McCrae & Costa, 2008; McCrae & Sutin, 2018), the Cybernetic Big Five Theory (DeYoung, 2015), or the three-layer model of personality (McAdams, 2015; McAdams & Olson, 2010; McAdams & Pals, 2006). Although each of these theoretical perspectives defines DTs and CAs somewhat differently, they are largely consistent regarding the cross-cultural universality and the genetic basis of DTs, and provide well-justified candidates for potential DTs (see Supplementary Table A1). They converge in considering so-called Big Five trait dimensions (i.e., neuroticism, extraversion, openness, agreeableness, and conscientiousness) and associated aspects, facets, and nuances as DTs, because they appear to describe cross-culturally universal and substantially heritable phenomena (McCrae et al., 2001, 2005; Yamagata et al., 2006).

All theories emphasize the specificity of CAs in relation to an individual's particular life condition. They are, however, less consistent regarding potential candidates for CAs (see Supplementary Table A1). For example, McAdams (2015) treated all more specific motivational

(what people want) and evaluative characteristics (what people value) as CAs (e.g., motives, goals, values, virtues, self-schemas, etc.). CAs are seen as more particularized and contextualized than DTs. McCrae and Costa (2008) did not necessarily limit CAs to the motivational spectrum, but similarly emphasized the particularity of CAs for everyday demands of human lives and provided a comparable list of potential CAs. DeYoung (2015) also outlined central motivational and evaluative aspects, but was more concrete in defining CAs in relation to an individual's particular life circumstances with *goals* as desired future states, *interpretations* as evaluations of the current states, and *strategies* as more or less automatized attempts to transform the current into desired states.

DeYoung (2015) emphasized several confusions about the distinction between DTs and CAs, depending on how they are conceived and measured. For example, self-schemas (e.g., self-esteem and self-efficacy) can be considered CAs as they depend on culturally specific criteria to judge oneself and social comparative processes (Marsh et al., 2020). However, they can also be considered DTs as they reflect global and core evaluations of the self. Accordingly, they can easily be put on a level with DT constructs, such as self-esteem with neuroticism (Judge et al., 2002) or social self-esteem with extraversion (Ashton & Lee, 2007). Similarly, moral virtues and values (e.g., honesty and fairness) “may be traits if they refer to culturally universal phenomena” (DeYoung, 2015, p. 40). In the HEXACO framework, fairness is a facet of honesty-humility, which is seen as a reasonable additional universal DT construct beyond the broad Big Five dimensions (Ashton & Lee, 2020). However, “an individual's explicit ranking of values would constitute a characteristic adaptation” (DeYoung, 2015, p. 40), because individual priorities of values and the importance of virtues for everyday moral decisions are rather idiosyncratic and shaped by people's cultural and religious context, even if many of the values and moral concerns refer to culturally universal phenomena (Haidt & Joseph, 2007; Schwartz et al., 2012).

A related problem of distinguishing between DTs and CAs is confounding of their measures. Even if items refer to general tendencies (e.g., “I am generally very extraverted”) instead of contextual manifestations (e.g., “I like parties and have lots of friends”), the assessment itself takes place within a specific measurement occasion confounded with situational and contextual influences. In other words, trait measures may tap contextual adaptations. One way to counteract these issues is to approximate DTs by aggregating over a wide range of items capturing trait-relevant (affective, cognitive, motivational, and behavioral) content across time and contexts. For example, when using different items, even if each item may be about a particular CA (e.g., social

interest), the total score could reflect the trait (e.g., extraversion) to which all those adaptations were related (DeYoung, 2015), “[s]o specific CA meanings [may] cancel each other, leaving a purer indicator of the underlying trait” (McCrae & Sutin, 2018, p. 153). In other words, each self-report on one’s own characteristic may reflect both a DT and a CA at the same time, but more abstract aggregates could reflect cross-contextually consistent DTs, whereas narrower measures may rather reflect concrete contextualized CAs. Thus, differences in the level of measurement abstraction and how DTs and CAs are measured (i.e., more or less context-related) have to be taken into account when comparing DTs and CAs.

Recently, Kandler and Rauthmann (2022) tried to harmonize different theoretical perspectives with their latent adaptation-state-trait model (see Table A1). They provided verbal and more formalized definitions of DTs and CAs (see also <https://osf.io/k4j8h/>). They defined DTs as characteristics of persons that are relatively consistent across situations and contexts, whereas CAs are defined as relatively stable characteristics of person-in-context units. Their model differentiates DTs from CAs ( $DT \neq CA$ ) and also integrates potential DTs into CAs by including trait-context interplay ( $CA = DT + \text{context} + DT \times \text{context}$ ). Further, it allows that CAs may reflect contextualized expressions of potentially underlying DTs (in line with McCrae & Costa, 2008) though they do not need to (according to McAdams, 2015, and DeYoung, 2015). They can reflect pure person  $\times$  context interactions (if  $CA = DT \times \text{context}$ ) or interactions plus contextual influences (if  $CA = \text{context} + DT \times \text{context}$ ).

Though the aforementioned theoretical perspectives define and list DTs and CAs slightly differently, they generally tend to postulate a fundamental genetic basis of individual differences in DTs and a more contextualized, socio-culturally plastic basis of individual differences in CAs. This distinction implies that CAs should be more

environmentally sensitive than DTs. This hypothesis can be tested empirically with the use of environmentally sensitive data, such as data including measures of environments (Asendorpf & Motti-Stefanidi, 2018) or allowing to distinguish environmental from genetic differences (Kandler, Penner, et al., 2019).

## 1.2 | Distinguishing environmental from genetic differences

Hundreds of twin studies have shown that about half of the variance in several human attributes, including personality characteristics, is attributable to genetic sources, while the remaining variance is mainly attributable to environmental sources including error of measurement (Kandler, Zapko-Willmes, et al., 2021; Polderman et al., 2015). However, most of these studies have focused on universal trait constructs (Johnson et al., 2008; Vukasović & Bratko, 2015). Moreover, most evidence for environmental and genetic contributions to personality differences is based on the classical twin design (CTD) which compares the similarities of monozygotic and dizygotic twin pairs. This design relies on several assumptions and thus has multiple limitations.

The CTD does not allow distinguishing broad-sense into several narrower<sup>1</sup> environmental sources of personality similarities and differences (see Table 1). The design can only be used to disentangle variance due to environmental factors shared by twin siblings from those not shared by them. However, environmental sources can contribute to twins’ similarity or differences because of different reasons. Twins’ similarity in DTs and particularly in CAs can be attributable to broad contextual factors (e.g., cultural, religious, and socio-economic background) shared by core family members within and across generations, such as familial influences generationally transmitted and thus

**TABLE 1** Specific environmental factors, examples, and consequences for family similarity

Factor	Example	Consequence
Intra-familial environmental transmission	Shared home environment, shared neighborhood	Increases the similarity of core family members
Sibling-specific (or twin-specific)	Shared peer influences, sibling interaction	Increases the similarity of siblings/twins only
Social homogamy	Within-generationally shared social, educational, and cultural background	Increases the similarity of siblings and spouses
Spouse-specific	Spousal interaction and assimilation	Increases spouse similarity, but decreases siblings/twins’ similarity
Individual-specific	Individual life events or subjective experiences of events shared with others	Decreases dyads’ similarity, increases individuality
Random error of measurement <sup>a</sup>	Unspecific artificial effects on the measurement	Artificially decreases dyads’ similarity

<sup>a</sup>No reliable environmental factor, but confounded with estimates of individual-specific nonshared environmental factors if not adjusted for.

shared by parents and their offspring reared together (i.e., *intra-familial environmental transmission*).

Twins' similarity can also be due to *environmental influences only shared by siblings* (or *twins*), which act to increase the similarity between siblings but not between parents and their offspring. Both kinds of influences must be differentiated from generation-specific social influences that can not only act to increase twins' similarity but also—and to the same extent—the similarity of other within-generational closely bonded dyads, such as friends and spouses. This source of spouse similarity due to shared social, educational, and cultural circumstances has been called *social homogamy* (Watson et al., 2004).

*Spouse-specific environmental influences* (e.g., spousal interaction) can alternatively or even additionally boost spouse similarity. To the same extent it can act to decrease twins' similarity because partners, who reflect important extra-familial others in one's own life that may influence personality development (Wagner et al., 2020), are typically not shared by twins. In addition, idiosyncratic *individual-specific environmental influences* not shared by any family members may act to increase one's individuality and thus inter-individual differences. It must be noted that objectively shared environments can act as those nonshared environmental influences when they are experienced (i.e., perceived, interpreted, and evaluated) in an idiosyncratic manner. However, individual environmental influences are confounded with *random error of measurement* and, thus, need to be adjusted for.

Another limitation of the CTD is that it does not allow differentiating between different (i.e., shared and not shared) environmental and different (i.e., additive and nonadditive) genetic sources of variance at the same time. Thus, narrow-sense heritability<sup>2</sup> cannot be differentiated from broad-sense heritability. Narrow-sense heritability only includes genetic differences due to *additive genetic factors* that refer to the combined effects of relevant genetic variants. Broad-sense heritability encompasses genetic variance attributable to additive and *nonadditive genetic factors*, the latter of which referring to interaction effects of genetic variants within and across gene loci. In addition, broad-sense heritability includes genetic variance due to assortative (i.e., nonrandom) mating which acts to increase or at least stabilize genetic variance in a population and the genetic similarity of family members (except in monozygotic twins). Additive genetic factors are shared between family members to the degree they are genetically related, whereas nonadditive genetic factors due to multiple gene  $\times$  gene interactions across gene loci are only shared by genetically identical twins.

Extending twin designs by including information from other relatives, such as parents and children of twins, can overcome the aforementioned limitations (Kandler,

Richter, et al., 2019; Keller et al., 2010). Such an extended twin family design (ETFD) allows estimations of shared environmental sources in the presence of nonadditive genetic sources of variance. If both sources are relevant but cannot be considered in the CTD, the heritability estimates would be inflated (see Boomsma et al., 2018, for an example regarding neuroticism). ETFDs can also consider specific forms of gene–environment interplay, such as nonrandom associations between genetic and familial influences transmitted from parents to their offspring (i.e., passive gene–environment covariance). Moreover, the extension of twin designs by including spouses of twins allows the differentiation between spouse similarity attributable to spouse-specific effects or shared social backgrounds (i.e., social homogamy) and genetically driven spousal assortment as a specific kind of active or evocative gene–environment transaction (Kandler et al., 2012, 2015).

### 1.3 | The current study

This study aims to compare self-report measures of personality characteristics,<sup>3</sup> commonly conceptualized as DTs (e.g., Big Five and related trait constructs) and CAs (e.g., interests, goals, values, virtues, and self-schemas; see Supplementary Table A2 for definitions of these constructs), regarding their assumed differences in genetic and environmental variance components. For this purpose, we use data from an ETFD across generations (incl. Twins plus their parents, offspring, and spouses) to disentangle different narrower environmental influences (Table 1) from additive and nonadditive genetic factors contributing to differences in measured personality characteristics. The environmental and genetic sources of variance can be combined to broad-sense environmentality (i.e., the entire environmental contribution to the common variance) and broad-sense heritability (i.e., the entire genetic contribution to the common variance), respectively. This allows us to test the following first hypothesis: *The entire environmental contribution to individual differences in measures of CAs is larger than the entire environmental contribution to individual differences in measures of DTs.*

However, as measures of DTs are typically broader in content and on a more abstract level than measures of CAs, and as aggregated CAs may have properties of DTs or even reflect DTs (DeYoung, 2015; McCrae & Sutin, 2018), the comparison between DTs and CAs and thus their differences regarding environmentality may be biased. To counteract this issue in our analyses, we also compare DT facets with DT domains and test a second (alternative) hypothesis: *The entire environmental contribution to individual differences in narrower facet-level measures is*



larger than the entire environmental contribution to individual differences in measures of broader dimensions. Both hypotheses were preregistered (<https://osf.io/q6tru>).<sup>4</sup> In addition, we examine which narrower genetic and environmental sources drive the difference between DTs and CAs regarding their broad-sense heritability and environmentality. The comparisons between DTs' and CAs' genetic and environmental variance components at different levels of measurement abstraction are adjusted for differential attenuation due to differences in the reliability of measurement.

## 2 | METHODS

### 2.1 | Sample

We analyzed the openly accessible data from the twin family study of the Study of Personality Architecture and Dynamics (SPeADy; Kandler, Penner, et al., 2019).<sup>5</sup> The first wave of data collection encompassed data from 570 families with complete twin pairs. We added data from 68 newly joined families with complete twin pairs from the second wave of data collection. The entire sample encompasses 638 complete twin pairs (age range: 14–88 years,  $M = 38.42$ ,  $SD = 20.05$ ) with 187 female and 53 male monozygotic (MZ) pairs and 227 female, 59 male, and 112 opposite-sex dizygotic (DZ) twin pairs.

For twin pairs within the age range 14–59 years, 203 mothers (age range: 37–87 years,  $M = 57.55$ ,  $SD = 11.71$ ) and 117 fathers (age range: 35–85 years,  $M = 59.40$ ,  $SD = 11.62$ ) provided self-reports on their personality characteristics. For twins within the age range 42–84 years, data from 92 female and 55 male children of twins (age range: 14–59 years,  $M = 30.39$ ,  $SD = 12.40$ ) are available. Only for seven twin pairs (aged 43–50), data from both their parents (aged 70–81) and their offspring (aged 14–24) are available. Moreover, 61 female and 167 male spouses of twins (age range: 16–89 years,  $M = 51.06$ ,  $SD = 15.00$ ) provided data. In sum, the entire sample includes 1971 individuals (1296 women, 66%) who range in age from 14 to 89 years. The sample cannot be treated as representative for the German population, but it is heterogeneous regarding age, sex, family status, and educational attainment (see Kandler, Penner, et al., 2019, for more details on the sample characteristics, recruitment procedure, and data collection).

### 2.2 | Measures

The SPeADy project aimed to use non-commercial measurement instruments with an acceptable balance

between brevity and psychometric quality of measurement, resulting in a broad spectrum of reliably measured characteristics. Detailed information and references to the specific measurement methods are listed in the Supplementary Table A2. Supplementary Table B1 comprises reliability estimates and 95% confidence intervals for these estimates.

We ran confirmatory factor analyses (CFAs) for each DT domain and CA based on their items as manifest variables and tested for measurement invariance (MI) across subsamples of family members using the statistical software JASP 0.16 (JASP Team, 2022). Metric MI (i.e., equal factor loadings) across subsamples is necessary to assume that structurally identical DT and CA constructs have been measured in each family member, allowing for the interpretation of family similarity based on correlations and the analysis of variance–covariance matrices of family members' characteristics. We used two standard procedures to assess relative model fit between models with different degrees of MI (configural, metric, scalar, and strict). First, we used the  $\Delta CFI < 0.01$  criterion where a constrained model should not show a decrease in the comparative fit index value larger than or equal to 0.01 (Cheung & Rensvold, 2002). Second, the standardized root mean square residual should not show an increase larger than or equal to 0.03, and thus  $\Delta SRMR < 0.03$  (Meade et al., 2008). An overview on MI testing can be found at <https://osf.io/wxap2/> (see also JASP data analyses and outputs at <https://osf.io/qfch5/files/> for details).

In addition, we estimated correlations and ran exploratory and confirmatory factor analyses using JASP to explore or confirm the structural convergence and divergence of selected sets of DT and CA measures. We also ran network analyses to explore whether or not expectable cluster structures appeared (i.e., whether facets of a domain clustered together). These analyses were based on data from Twin A and Twin B subsamples, to which one twin of each pair was assigned. As a consequence, both subsamples included unrelated and thus independent persons.

#### 2.2.1 | Dispositional trait measures

The Big Five Inventory 2 (BFI-2; Danner et al., 2019; Soto & John, 2017) and the 60-item HEXACO Personality Inventory Revised (HEXACO-60; Ashton & Lee, 2009; Moshagen et al., 2014) were used as measures of DTs. These questionnaires together capture 11 systematically associated broader trait domains and 39 facet-level traits, which overlap more or less conceptually and empirically and should be primarily associated with one broader trait domain each. Internal consistencies of domain scores

were good (averaged  $\omega = 0.80$ ), ranging from  $\omega = 0.74$  (for HEXACO Emotionality) to  $\omega = 0.88$  (for BFI-2 Conscientiousness). Given the small number of items (2 to 4) to capture facet-level traits, the internal consistencies of facet-level trait measures were acceptable (averaged  $\omega = 0.64$ ), ranging from  $\omega = 0.42$  (for HEXACO Unconventionality) to  $\omega = 0.87$  (for BFI-2 Aesthetic Sensitivity). Metric MI across family members can be assumed for all HEXACO-60 and BFI-2 measures.

To examine the convergence of the HEXACO-60 and BFI-2 trait constructs and structural validity of a common hierarchical trait structure, we estimated correlations and ran exploratory factor analyses (EFAs) with promax rotation based on the 24 HEXACO and 15 BFI facet scores for Twin A and Twin B subsamples. We expected six dimensions that can be identified as Honesty-Humility, Negative Emotionality or Neuroticism, Extraversion, Agreeableness, Conscientiousness, and Openness to Experience or Open-Mindedness. The analyses yielded systematic HEXACO-BFI links and confirmed the expected six higher-order trait domains (see Supplementary Figure B1, Output B1, and JASP data analyses and outputs at <https://osf.io/qfch5/files/> for more details).

## 2.2.2 | Measures of characteristic adaptations

We focused on 43 constructs typically treated as CAs, including: six goals, six interest domains, five moral concerns, 19 basic value priorities, religiousness, self-esteem, internal and external control beliefs, self-efficacy, as well as affective and cognitive well-being (see Supplementary Table A2 for definitions and measures). Internal consistencies were acceptable (average  $\omega = 0.72$ ), ranging from  $\omega = 0.45$  to  $\omega = 0.88$  (see Supplementary Table B1). As several previous studies have shown systematic intercorrelations between selective sets of CAs, we ran correlation as well as factor analyses to examine these links (see JASP data analyses and outputs at <https://osf.io/qfch5/files/> for more details).

### Goals

Power, Achievement, Affiliation, and Intimacy goals were captured with the 24-item version of the Unified Motive Scale (UMS-24; Schönbrodt & Gerstenberg, 2012). Personal Growth and Health goals were measured with ten items taken from the German Aspirations Index (Klusmann et al., 2005). Internal consistencies were acceptable to good (average  $\omega = 0.80$ ), ranging from  $\omega = 0.70$  (for Personal Growth) to  $\omega = 0.87$  (for Power and Affiliation). Metric MI across family members could be assumed for all goal measures. Power and Achievement goals ( $r = 0.51$ ), Affiliation and Intimacy goals ( $r = 0.39$ ), and Personal Growth and Health goals ( $r = 0.44$ )

showed moderate to substantial links, whereas other links were small. Accordingly, parallel analyses of eigenvalues and CFAs suggested three higher-order dimensions.

### Interests

Interests were measured with the Situational Interest Test (SIT; Stangl, 2022), which is a non-commercial German questionnaire to assess Realistic, Intellectual, Artistic, Social, Enterprising, and Conventional interests based on the hexagon model by Holland (1997). On thirty items with a forced-choice response format, participants decided which of two activities associated with specific leisure or occupational contexts they preferred more. This ipsative format of interest assessment typically leads to lower internal (cross-item) consistency but higher validity estimates (Nelling et al., 2015). Accordingly, internal consistencies were comparatively lower (average  $\omega = 0.61$ ), ranging from  $\omega = 0.54$  (for Intellectual interests) to  $\omega = 0.73$  (for Artistic interests). The  $\Delta CFI < 0.01$  criterion indicated no metric MI, except for Artistic interests. However, the  $\Delta SRMR < 0.03$  criterion suggested that metric MI can be assumed for all interest measures. Due to the forced-choice response format, the intercorrelations between interests tended to be negative. They ranged from  $r = 0.07$  between Conventional and Realistic interests to  $r = -0.51$  between Artistic and Conventional interests. Correlations with other CA measures were rather small ( $-0.25 < rs < 0.25$ ), except for the link between Enterprising interests and Power goals in the Twin A ( $r = 0.36$ ) and Twin B ( $r = 0.28$ ) subsamples.

### Morality and values

Individual differences in five moral concerns (Care vs. Harm, Fairness vs. Cheating, Authority vs. Subversion, Ingroup/Loyalty vs. Betrayal, and Purity/Sanctity vs. Degradation) were measured with an adapted German version of the 20-item Moral Foundations Questionnaire (MFQ-20; Graham et al., 2011). The 57-item Portrait Value Questionnaire (PVQ-57RR; Schwartz et al., 2012) was used to measure individual differences in value priorities regarding 19 basic values (see Supplementary Table A2 for all labels). Internal consistencies were generally acceptable (average  $\omega = 0.71$ ), ranging from  $\omega = 0.45$  (for Ingroup/Loyalty vs. Betrayal) to  $\omega = 0.87$  (for Tradition). Metric MI could be assumed for all MFQ and PVQ measures, except for Achievement ( $\Delta CFI = 0.018$  and  $\Delta SRMR = 0.039$ ). To receive individual value priorities, we calculated the relative importance of each value to each person by centering each person's responses on his or her own mean across their 19 value scores. This resulted in the typical circular correlational structure of value priorities (see Supplementary Figure B2 as well as JASP data analyses and outputs at <https://osf.io/qfch5/files/> for further analyses supporting

the circular structure). Measures of moral concerns and value priorities are linked systematically due to common contents (see Zapko-Willmes et al., 2021, for analyses based on the twin sample). Moreover, Achievement and Power priorities showed positive links to Achievement and Power goals, ranging from  $r = 0.36$  to  $r = 0.59$ .

### Religiousness

Using the 7-item Centrality of Religiosity Scale (CRSi-7; Huber & Huber, 2012), we measured Religiousness. The internal consistency was high with  $\omega = 0.88$  and strict MI could be assumed. Religiousness was mainly uncorrelated with other CA measures with  $-0.20 < r_s < 0.20$ , except for the moderate link with Tradition values ( $r_s = 0.33$  and  $0.38$  in the Twin A and Twin B subsamples).

### Self-schemas

The self-schemas Self-esteem, Internal and External Control Beliefs, and Self-efficacy were measured with short versions of established questionnaires, namely the Rosenberg Self-Esteem Scale (Rosenberg, 1965; Thönnissen et al., 2020), a measure of Internal and External Control Beliefs (Kovaleva, 2012), and the General Self-Efficacy Scale (Beierlein et al., 2014). In addition, the German Satisfaction With Life Scale (Glaesmer et al., 2011) and six items from the Habitual Subjective Well-Being Scale (Dalbert, 1992) were used to assess Cognitive and Affective Well-being, respectively. Given the small number of items, the internal consistencies can be treated as acceptable to good (average  $\omega = 0.74$ ), ranging from  $\omega = 0.46$  (for External Locus of Control) to  $\omega = 0.88$  (for Affective Well-being). Metric MI can be assumed for all measures, except for Self-esteem ( $\Delta CFI = 0.018$  and  $\Delta SRMR = 0.039$ ). The intercorrelations of self-schemas were moderate to substantial in absolute size, ranging from  $r = -0.27$  between Self-efficacy and (lower) External Control Beliefs to  $r = 0.64$  between Cognitive and Affective Well-being, indicating at least one common dimension accounting for the intercorrelations of self-schemas (see JASP data analyses and outputs at <https://osf.io/qfch5/files/> for more details on correlation analyses and CFAs).

### 2.2.3 | Adjustment for age and sex differences

Because age effects on DTs and CAs could increase twin similarity but decrease correlations between other family members of different ages, and because sex differences could increase the differences between opposite-sex compared to same-sex family members, we used a standard regression procedure for family data

to correct each DT and CA score for age and sex differences (McGue & Bouchard, 1984). Standardized residual scores derived from these regressions were used in the following analyses.

## 2.3 | Analyses

### 2.3.1 | Family correlations

First, we examined the similarity of family member dyads via intra-class correlations (*ICCs*) using the statistical software IBM SPSS 26.0.0 (<https://www.ibm.com/products/spss-statistics>). The syntax and output files are available at <https://osf.io/qfch5/files/>. These *ICCs* allow first insight into potential differences in family similarity regarding DT and CA measures, indicating different sources underlying DT and CA variance. For comparisons between DT and CA measures based on family correlations, *ICCs* were corrected for attenuation due to the unreliability of measurement by dividing the *ICCs* by internal consistency  $\omega$ .

### 2.3.2 | Extended twin family modeling

Second, to estimate different environmental and genetic sources of variance in DT and CA measures, we analyzed the data from complete twin pairs plus their parents and their offspring in an extended twin family model (ETFM). This structural equation model is a four-group model (MZ twins + parents, MZ twins + offspring, DZ twins + parents, and DZ twins + offspring) that allows disentangling several environmental effects from several genetic influences and passive gene–environment covariance, taking assortative mating of twins' parents into account. The four-group ETFM is described in detail in Supplement D.

In the ETFM, individual differences can be decomposed into variance due to (1) additive genetic sources, which can be inflated or deflated by (2) assortative mating, (3) nonadditive genetic factors, (4) passive gene–environment covariance, (5) intra-familial environmental transmission, (6) sibling-specific shared environmental sources, and (7) environmental sources not shared by family members (incl. measurement error variance; see Supplementary Table D1). Assortative mating is estimated based on the covariance of twins' parents. All genetic and environmental factors contribute to MZ twins' similarity, except for environmental factors not shared by family members and random error of measurement. The same factors that contribute to the MZ twins' similarity contribute to the DZ twins' resemblance, except for nonadditive genetic sources due to gene-by-gene interactions. In addition, DZ twins only share, on average, 50% of additive genetic



factors, whereas those effects are completely shared by genetically identical MZ twins. In case of positive or negative assortative mating, however, DZ twins can share more or less than half of the additive genetic factors. As a consequence, additive genetic variance can be inflated in case of positive correlations of the characteristics of twins' parents and deflated in case of negative correlations. Parent-child covariance also depends on assortative mating and is attributable to genetic transmission, non-genetic parental transmission, and passive gene-environment covariance. Passive gene-environment covariance represents a non-random link between genetic and familial environmental factors transmitted from parents to their offspring as a function of parental characteristics (see Supplement D for more details).

### 2.3.3 | Spouses-of-twins modeling

Third, we ran spouses-of-twins model (SoTM) analyses based on structural equation modeling of the data of MZ and DZ twins and their respective spouses. The SoTM is a two-group model and described in detail in Supplement E. It allows us to estimate further sources of environmental variance, namely those that act to increase spouse similarity. Spouse similarity can be attributed to phenotypic assortment regarding a characteristic that acts to increase phenotypic and, thus, the underlying genetic variance in this characteristic in a population as well as the genetic similarity of siblings, except for genetically identical MZ twins. As phenotypic assortment is partly driven by genetic factors, it leads to larger correlations between MZ twins' spouses compared to DZ twins' spouses.

Spouse similarity can, however, also arise due to environmental sources (Kandler et al., 2012, 2015). The SoTM differentiates environmental factors of spouse similarity shared by all members of a family constellation—that is, spouses, brothers-in-law, and sisters-in-law (i.e., social homogamy)—from environmental sources only shared by spouses (i.e., spouse-specific experiences or interaction). If those environmental sources of spouse similarity play a role, then the contribution of assortative mating to the genetic variance is overestimated in ETFM analyses. An overview of differences of variance decomposition properties between ETFMs and SoTMs and their advantages compared with the classical twin model (CTM) is presented in Table 2 (see also Supplement E for more details). In summary, the SoTM allows decomposing variance into components due to (1) additive genetic sources (more or less inflated/deflated by assortative mating), (2) nonadditive genetic factors, (3) social homogamy, (4) twin-specific shared environmental factors, (5) spouse-specific shared environmental sources, and (6) environmental factors

not shared by twins and spouses (incl. error variance; see Supplementary Table E1).

### 2.3.4 | Model fitting and parameter estimation procedures

According to the preregistered analysis plan (<https://osf.io/q6tru>), all SEM analyses of family data corrected for age and sex differences were run using the statistical software package Mx ([vipbg.vcu.edu/resources/statistical-software/mxgui/](http://vipbg.vcu.edu/resources/statistical-software/mxgui/)). We used full information maximum likelihood procedures to handle missing data. For determining if one model parameter was significantly different from zero, we used model-based 95% confidence intervals. All ETFM and SoTM Mx scripts for each of the 93 variables and input data files can be found at <https://osf.io/qfch5/files/>.

### 2.3.5 | Hypotheses testing

As preregistered, we used one-sided Student's *T*-tests and nonparametric Mann Whitney *U*-tests based on the standard  $p < .05$  to examine the expected differences between groups of variables (Hypothesis 1: DT domains/facets < CAs vs. Hypothesis 2: DT domains < DT facets) regarding their entire environmentality ( $Env^2$ ). We first tested for differences in roughly estimated environmentality as the inverse of rough heritability estimates ( $Env^2 = [1 - h^2] / \omega$ ) based on twin ICCs: If  $ICC_{MZ} \leq 2 \times ICC_{DZ}$ , then  $h^2 = 2 \times (ICC_{MZ} - ICC_{DZ})$ ; and if  $ICC_{MZ} > 2 \times ICC_{DZ}$ , then  $h^2 = ICC_{MZ}$ . In addition, we tested for differences using *T*- and *U*-tests on the basis of the sum of all standardized environmental variance components derived from the ETFM, corrected for attenuation due to error of measurement:  $Env^2 = (x + s^2 + [e^2 - (1 - \omega)]) / \omega$ . Thus, all standardized genetic components and the component due to passive gene-environment covariance were excluded. Similarly, we tested for differences in the sum of all standardized environmental components derived from the SoTM:  $Env^2 = (t^2 + u^2 + [e^2 - (1 - \omega)]) / \omega = (t^2 + u^2 + ve^2 + [(e^2 - ve^2) - (1 - \omega)]) / \omega$  (see Supplements D and E for model parameter descriptions).

## 3 | RESULTS

### 3.1 | Family correlations

As shown in Supplementary Tables C1 and C2, MZ twin ICCs for DT and CA measures were substantial and

**TABLE 2** Specific environmental, genetic, and gene–environment covariance components and decomposition properties of different twin family models

Component	Decomposition properties of CTM, ETFM, and SoTM
Intra-familial environmental transmission	<ul style="list-style-type: none"> <li>• CTM and SoTM: Cannot be disentangled from other components due to environmental influences shared by twins</li> <li>• ETFM: Can be estimated via non-genetic parent–child similarity</li> </ul>
Sibling-specific (or twin-specific) environmental	<ul style="list-style-type: none"> <li>• CTM: Cannot be disentangled from other components due to environmental influences shared by twins</li> <li>• ETFM and SoTM: Can be estimated via twin-specific non-genetic similarity</li> </ul>
Social homogamy	<ul style="list-style-type: none"> <li>• CTM and ETFM: Cannot be disentangled from other components due to environmental influences shared by twins</li> <li>• SoTM: Can be estimated via non-genetic similarity across twins and their spouses</li> </ul>
Spouse-specific environmental	<ul style="list-style-type: none"> <li>• CTM and ETFM: Cannot be disentangled from other components due to environmental influences not shared by twins</li> <li>• SoTM: Can be estimated via spouse-specific residual correlations</li> </ul>
Individual-specific environmental	<ul style="list-style-type: none"> <li>• CTM and ETFM: Cannot be disentangled from other environmental influences not shared by twins</li> <li>• SoTM: Can be estimated as variance due to effects neither shared by twins nor by spouses</li> </ul>
Additive genetic	<ul style="list-style-type: none"> <li>• CTM and SoTM: Can be estimated, but often inflated or deflated due to different reasons</li> <li>• ETFM: Allows more precise estimates</li> </ul>
Nonadditive genetic	<ul style="list-style-type: none"> <li>• CTM and SoTM: Can be disentangled from additive genetic variance under specific assumptions, but is often underestimated</li> <li>• ETFM: Allows more precise estimates</li> </ul>
Phenotypic assortment	<ul style="list-style-type: none"> <li>• CTM: Cannot be estimated</li> <li>• ETFM: Can be estimated as co-path between parents of twins</li> <li>• SoTM: Modeled as co-path between twins and their spouses, adjusted for social homogamy and spouse-specific effects</li> </ul>
Passive gene–environment covariance	<ul style="list-style-type: none"> <li>• CTM and SoTM: Cannot be considered and estimated</li> <li>• ETFM: Considered and estimated as the link between genetic and environmental factors transmitted from parents to their offspring</li> </ul>

*Note:* CTM: classical twin model of monozygotic (MZ) and dizygotic (DZ) twin pairs reared together; ETFM: extended twin family model of reared-together MZ and DZ twin pairs plus the parents of younger twins and children of older twins; SoTM: spouses-of-twins model of reared-together MZ and DZ twin pairs plus their spouses. See also Supplements D and E.

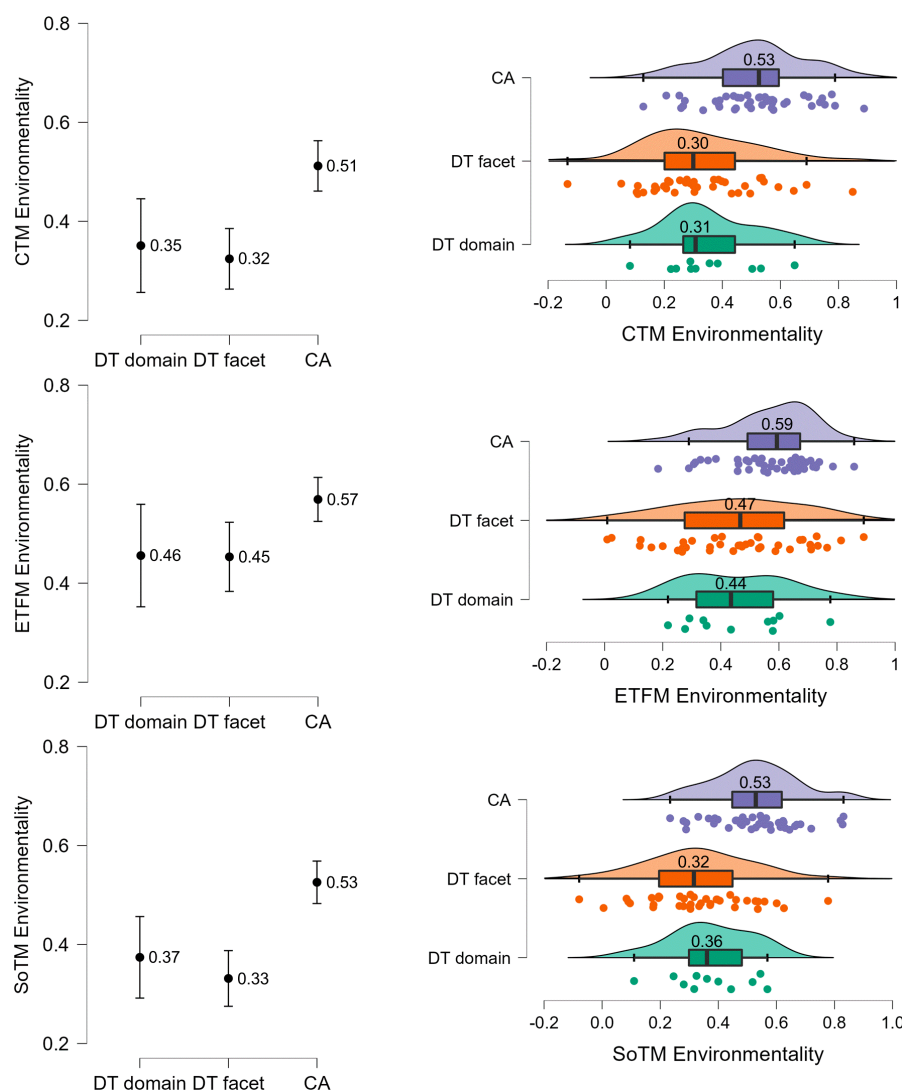
significantly higher than all other family correlations (i.e., the 95% confidence intervals of adjusted ICCs did not overlap), indicating substantial contributions of genetic influences to individual differences in both DT and CA measures. The MZ twin ICCs tended to be smaller for CA measures (except for religiousness) than for DT domains and facets, indicating—in line with Hypothesis 1—larger environmental influences (not shared by twins) on variance in CA measures. The corrected family correlations suggest only marginal differences in family similarity between DT domain and facet measures, contradicting Hypothesis 2.

Using twin ICCs, we estimated CTM-based environmentality as the inverse of heritability estimates corrected for attenuation due to measurement error. The top of Figure 1 visualizes differences in these environmentality estimates between DT domain, DT facet, and CA measures. As can be seen there, and consistent with Hypothesis 1, both *T*- and *U*-tests yielded statistically significantly larger CTM-environmentality in CA measures

compared to DT domains and facets, whereas no significant differences were found between DT domains and DT facets (see Table 3).

Family correlations suggest two further particularities of CA compared to DT measures. First, there were significant spouse similarities in all CA measures (except for interests; see Supplementary Tables C1 and C2). Second, family similarity in religiousness was relatively high with moderate to substantial similarity in genetically unrelated family members, such as sisters/brothers-in-law, indicating large familial environmental influences.

As family correlations also suggest higher DZ twin similarity compared to other first-degree family relatives across all DT and CA measures (see Tables C1 and C2), sibling- or twin-specific environmental sources of variance are plausible. Moreover, MZ twin ICCs tended to be higher than twice the DZ twin ICCs, indicating the presence of nonadditive genetic factors. Hence, focusing on twin similarity only may overestimate heritability and underestimate environmentality.



**FIGURE 1** Environmental differences between measures of dispositional traits and characteristic adaptations based on different twin family models. Left side: Interval plots with means and 95% CIs. Right side: Raincloud plots with medians, quartiles, and scattering of estimates of environmentality. Estimates are corrected for measurement error and based on the classical twin model (CTM), extended twin family model (ETFM), and spouses-of-twins model (SoTM).

### 3.2 | Extended twin family modeling

The ETFM takes both sibling-specific environmental and nonadditive genetic factors in addition to other sources of variance into account, and thus goes beyond the CTM. Model parameter and variance component estimates for all 93 DT and CA measures are presented in the Supplementary Tables D2 and D3. Figures D2 and D3 summarize the two genetic and the three environmental as well as passive gene-environment covariance components for DT domains, DT facets, and CA measures corrected for attenuation due to unreliability.

On average, the attenuation-corrected broad-sense environmentality estimates based on ETFMs were larger compared to those based on the CTM. Similar to the CTM-based results, however, environmentality did not differ markedly between DT domains and facets (about 45%, see Figure 1), contradicting Hypothesis 2. In line with Hypothesis 1, however, the environmentality estimates for DT domains and facets were smaller than those of CA

measures (57%). Both *T*- and *U*-tests provided support for Hypothesis 1, but not for Hypothesis 2 (see Table 3).

### 3.3 | Spouses-of-twins modeling

In a further step, we ran SoTM analyses for all 93 variables to estimate environmental sources of spouse similarity. The results of the SoTM analyses are presented in the Supplementary Tables E2 and E3. Figures E2 and E3 subsume the genetic and environmental components for DT domains, DT facets, and CA measures corrected for attenuation due to unreliability. On average, the corrected broad-sense SoTM-based environmentality estimates differed slightly between DT domains and facets (37% vs. 33%, see Figure 1). Generally, the environmentality for DT domains and facets were smaller than those of CA measures (53%).

As was already reported for CTM- and ETFM-based environmentality, *T*- and *U*-tests also yielded statistically significantly larger SoTM-based environmentality of CAs

TABLE 3 Hypothesis testing

Test → Hypothesis	Model	Test	Statistic	p	$\Delta$	Effect	90% CI	
						size	LL	UL
Environmentality of DT domains $\geq$ CAs ( $df = 52$ ) → Hypothesis 1: DT domains < CAs	CTM	Stud. <i>T</i>	<b>−2.83</b>	<b>.003</b>	<b>−0.16</b>	<b>−0.96</b>	<b>−1.53</b>	<b>−0.38</b>
		M-W <i>U</i>	<b>115</b>	<b>.005</b>	<b>−0.17</b>	<b>−0.51</b>	<b>−0.71</b>	<b>−0.24</b>
	ETFM	Stud. <i>T</i>	<b>−2.18</b>	<b>.017</b>	<b>−0.11</b>	<b>−0.74</b>	<b>−1.30</b>	<b>−0.17</b>
		M-W <i>U</i>	<b>145</b>	<b>.025</b>	<b>−0.11</b>	<b>−0.39</b>	<b>−0.62</b>	<b>−0.08</b>
	SoTM	Stud. <i>T</i>	<b>−3.14</b>	<b>.001</b>	<b>−0.15</b>	<b>−1.06</b>	<b>−1.64</b>	<b>−0.48</b>
		M-W <i>U</i>	<b>109</b>	<b>.003</b>	<b>−0.15</b>	<b>−0.54</b>	<b>−0.73</b>	<b>−0.27</b>
Environmentality of DT facets $\geq$ CAs ( $df = 80$ ) → Hypothesis 1: DT facets < CAs	CTM	Stud. <i>T</i>	<b>−4.65</b>	<b>&lt;.001</b>	<b>−0.19</b>	<b>−1.03</b>	<b>−1.41</b>	<b>−0.64</b>
		M-W <i>U</i>	<b>379.5</b>	<b>&lt;.001</b>	<b>−0.20</b>	<b>−0.55</b>	<b>−0.68</b>	<b>−0.38</b>
	ETFM	Stud. <i>T</i>	<b>−2.80</b>	<b>.003</b>	<b>−0.12</b>	<b>−0.62</b>	<b>−0.99</b>	<b>−0.25</b>
		M-W <i>U</i>	<b>568.5</b>	<b>.006</b>	<b>−0.12</b>	<b>−0.32</b>	<b>−0.50</b>	<b>−0.12</b>
	SoTM	Stud. <i>T</i>	<b>−5.44</b>	<b>&lt;.001</b>	<b>−0.19</b>	<b>−1.20</b>	<b>−1.20</b>	<b>−0.80</b>
		M-W <i>U</i>	<b>328.5</b>	<b>&lt;.001</b>	<b>−0.19</b>	<b>−0.61</b>	<b>−0.73</b>	<b>−0.46</b>
Environmentality of DT domains $\geq$ facets ( $df = 48$ ) → Hypothesis 2: DT domains < DT facets	CTM	Stud. <i>T</i>	0.42	.660	0.03	0.14	−0.42	0.70
		M-W <i>U</i>	241	.736	0.03	0.12	−0.20	0.42
	ETFM	Stud. <i>T</i>	0.04	.514	0.00	0.01	−0.55	0.57
		M-W <i>U</i>	215	.509	0.00	0.00	−0.31	0.32
	SoTM	Stud. <i>T</i>	0.73	.765	0.04	0.25	−0.32	0.81
		M-W <i>U</i>	252	.813	0.04	0.18	−0.15	0.47

Note: Estimates of environmentality are corrected for measurement error. DT: dispositional trait; CA: characteristic adaptation; CTM: classical twin model; ETFM: extended twin family model; SoTM: spouses-of-twins model. For Student's *T*-test (Stud. *T*), location parameter  $\Delta$  is given by mean difference and effect size is given by Cohen's *d*. For Mann–Whitney *U*-test (M-W *U*), location parameter  $\Delta$  is given by Hodges–Lehmann estimate and effect size is given by rank biserial correlation. Significant parameters are bold-faced.

compared to DT domains and facets, providing support for Hypothesis 1 across all genetically informative models. Furthermore, environmentality was not statistically significantly larger for DT facets compared to DT domains across different model estimates, contradicting Hypothesis 2 (see Table 3).

### 3.4 | Additional explorative results

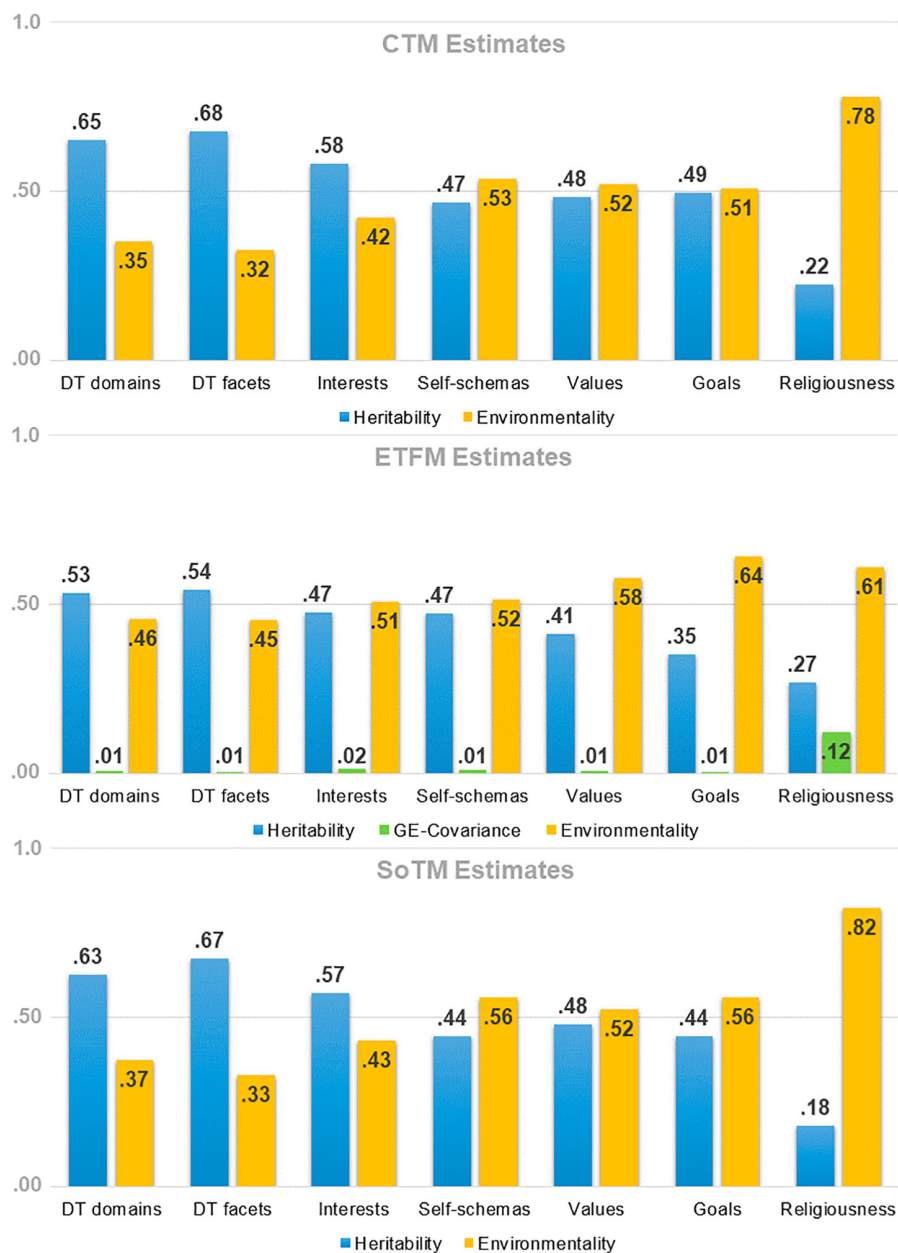
Higher environmentality of CA measures was consistent across different candidates of potential CAs, namely interests, self-schemas, value priorities, goals, and religiousness (see Figure 2). Only for interests, environmental sources accounted for, on average, less than 50% of variance considering CTM- and SoTM-based estimates corrected for measurement error. Environmentality would be underestimated when both nonadditive genetic and environmental factors shared by twins acted to increase variance but cannot be fully estimated in presence of each other. Both components however, can be estimated in the ETFM. Therefore, ETFM-based estimates of environmentality generally tended to be higher compared to CTM- and SoTM-based environmentality. Considering ETFM

estimates, environmental influences accounted for more than 50% of the error-corrected variance in goals, interests, morality, value priorities, religiousness, and self-schemas, whereas the reverse (<50%) was true for DT measures.

Highest levels of environmentality were found for religiousness, except for ETFM-based estimates. Here, passive gene–environment covariance could be considered. It explained 12.4% of variance in religiousness. For other CA measures, variance due to passive gene–environment covariance was generally small (<5%) or not significant, except for tradition value priorities (6.0%) and conventional interests (5.9%; see Supplementary Table D3). Neither for DT domains nor for DT facets, the passive gene–environment covariance component was larger than 5%.

On average, the corrected broad-sense environmentality estimates did not differ markedly between DT domains and facets, but they tended to differ regarding environmental variance due to effects shared and not shared by twins. DT facets showed, on average, larger environmental components due to familial transmission, social homogamy, sibling-specific and twin-specific influences, and spouse-specific influences, whereas the environmental component due to individual-specific effects was larger for DT domains (see Supplementary Figures D2 and E2). Explorative





**FIGURE 2** Differences in genetic and environmental variance components between measures of dispositional traits and characteristic adaptations. Estimates are standardized, corrected for unreliability of measurement, and based on the classical twin model (CTM), the extended twin family model (ETFM), and the spouses-of-twins model (SoTM).

post-hoc *T*- and *U*-tests on differences in these variance components between DT domains and facets, however, were not statistically significant (see Tables F3 to F5).

Further explorative *T*- and *U*-tests based on SoTM estimates indicated that additive genetic components were larger for DT domains and facets compared to CAs (see Supplementary Table F1 and Figure F1), whereas the tests based on ETFM estimates suggested that nonadditive genetic components were larger and the gene–environment covariance components smaller for DT facets compared to CAs (see Tables F2 to F3 and Figures F2 to F3). The latter, however, was primarily due to the relatively large passive gene–environment covariance component in religiousness compared to other measures.

Furthermore, the ETFM-based nonshared environment components were significantly smaller for DT

domains and facets compared to CAs (see Supplementary Table F5 and Figure F4). SoTM analyses suggested that these differences were primarily due to individual-specific components. Although statistically not significant, spouse-specific influences also tended to be larger for CA compared to DT measures (see Figures F5 and F6). Looking at general spouse similarity, across all spouses (between twins and their partners and between twins' parents), statistically significant positive spouse correlations were found for the DT domains Honesty-Humility (0.22), Openness (0.31), and Open-Mindedness (0.14). Spouses showed significant correlations in eight of 39 DT facets, ranging from  $r = 0.12$  (for Sincerity) to  $r = 0.37$  (for Aesthetic Appreciation). In 25 of 43 CA measures, spouse correlations were statistically significant, ranging from  $r = 0.12$  (for Stimulation priorities) to  $r = 0.54$  (for

Religiousness) (see ICCs at <https://osf.io/qfch5/files/> for all estimates and 95% CIs). We did not find statistically significant negative spouse correlations.

## 4 | DISCUSSION

### 4.1 | Broad-sense environmentality and heritability

The results consistently supported Hypothesis 1 and contradicted Hypothesis 2. The lower environmentality of DTs compared to CAs are in line with the Five-Factor Theory (e.g., McCrae & Sutin, 2018), the Cybernetic Big Five Theory (DeYoung, 2015), or the three-layer model of personality (McAdams, 2015) that all proposed CAs as more context-sensitive and particularized in individual life circumstances. Further, in line with the propositions of these theoretical perspectives outlined in the introduction (see also Supplementary Table A1), no differences in environmentality between higher-order DT domains and more specific facets could be found after controlling for differences in internal consistencies of respective measures. The larger genetic component compared to CAs and no differences in this regard between DT domains and facets provided further support for a genetic architecture underlying the hierarchical structure of trait models (McCrae et al., 2001; Yamagata et al., 2006).

In their review on the genetics of personality, Turkheimer et al. (2014) mentioned that “when reliability is accounted for, the proportion of heritable variance does not seem to vary substantially by level of analysis” (p. 521). Our study provides support for this claim, at least for DT domains and facets. However, when it comes to the DT–CA distinction, the allegedly more contextualized CAs indeed appeared to be more environmental. According to our results, environmental (and genetic) variance components varied across personality characteristics. This is in line with the heritability criterion outlined as one of seven criteria by Kandler and Rauthmann (2022) to identify DTs and separate them from other personality characteristics, taking definitional and measurement issues into account.

Our findings also provide support for the validity of the operationalization of these constructs. Measures of DTs, as used in this study, that should theoretically capture more universal, less context-dependent characteristics tended to be more heritable and showed substantially higher MZ twin (in comparison to DZ twin) correlations than our selection of measures of CAs, even after adjusting for unreliability. The CA measures that should theoretically capture more particularized, context-sensitive characteristics tended, at least on average, to be somewhat more environmental. This indicates that the properties of

the measures used in our study are indeed linked to the definitions of DTs and CAs that should be measured.

On a very general level of environmentality, the estimates did not vary across different twin family designs. The DT–CA difference in broad-sense environmentality were consistent across CTM, ETFM, and SoTM data analyses. Thus, the classical twin design based on information of the similarity of monozygotic twins compared to the similarity of dizygotic twins appeared to be sufficient to test differences in environmentality between DTs and CAs from a general point of view. More fine-grained exploratory analyses, however, yielded some variation in narrow-sense environmentality and heritability, respectively, across ETFM and SoTM estimates.

### 4.2 | Narrow-sense environmentality and heritability

Across all DT and CA constructs, the nonadditive genetic components were larger when estimated with the ETFM compared to the SoTM (compare Supplementary Figures D2 and E2: 23%, 31%, and 20% versus 15%, 19%, and 13%). Similar differences appeared for sibling-specific shared environmental components (14%, 18%, and 15% versus 6%, 8%, and 12% twin-specific environmental plus social homogamy components in the SoTM). In the SoTM (as in the CTM), either twin-specific shared environmental or nonadditive genetic influences can be estimated. If both are influential but cannot be estimated in the presence of each other, this would lead to an overestimation of the additive genetic component in SoTM analyses. This trend is evident by comparing SoTM-based estimates in Figure E2 (48% for DTs and 35% for CAs) with ETFM-based estimates in Figure D2 (30% for DT domains, 23% for DT facets, and 22% for CAs). This difference accounts for the inconsistent additional exploratory test results across ETFM and SoTM estimates regarding which genetic factors—the additive or the nonadditive influences—drove the differences in DTs' and CAs' heritability.

Additional exploratory analyses based on ETFM estimates suggested that passive gene–environment covariance played a more important role for CAs. However, this DT–CA difference appeared to be driven by only a few characteristics (see Figure F3). Only for religiousness, tradition values, and conventional interests, passive gene–environment covariance was statistically significant or accounted for more than 5% of their variance. Further research may help shed more light on such potential differences in the etiology of DTs' and CAs' variances. In any case, these findings showcase the value of extending twin data by adding information from parents and children of twins to detect more specific differences in the etiology of

individual differences in personality characteristics within and across classes of DTs and CAs.

Spouse similarity was negligible for DTs, except for moderate spouse correlations in honesty-humility and openness to experiences (and related facets). For CAs, however, a higher number of statistically significant spouse correlations was found, including a substantial spouse similarity for religiousness in line with previous research (Kandler, 2021). Looking at the sources of these spouse correlations by using SoTMs yielded that beyond phenotypic assortment, environmental sources tended to be more important for spouse similarity in CAs. Social homogamy and spouse-specific environmental sources accounted for, on average, 13% of the variance in CAs versus 8% for DT facets and 6% for DT domains (see Figure E2). In particular, the spouse-specific component due to spousal effects that decreases the similarity of twins but increases the similarity of spouses appeared to play an important role (on average 6% for CAs versus 3% for DTs). The importance of spouses as one's everyday social or shared partner's environment for CAs is again consistent with the theorized distinctions between DTs and CAs, as CAs have been proposed to be more particularized in relation to an individual's everyday life (DeYoung, 2015; McAdams, 2015).

Interestingly, we found significant spouse similarity for honesty-humility and openness, those trait dimensions that also showed systematic associations with value priorities (e.g., Anglim et al., 2017; Lee et al., 2010). This allows at least two possible implications: Either the measures of honesty-humility and openness confound CA aspects or they even reflect CAs more than the other four potential DT dimensions of the HEXACO (or Big Five) trait framework. In line with the latter position, the temperamental basis for neuroticism (e.g., negative affectivity), extraversion (e.g., activity and sociability), agreeableness (e.g., interpersonal effortful control), and conscientiousness (e.g., intrapersonal effortful control) can be observed very early in life, whereas openness and honesty-humility are typically less often associated with early temperamental dispositions (McAdams, 2015; Rothbart, 2007).

### 4.3 | Limitations and outlook for future research

Although our study has a number of strengths, it is not without limitations. One clear limitation is the sole reliance on self-reports of DTs and CAs. Such reports rely on subjective perceptions, interpretations, and evaluations, which are in turn defined as CAs and thus do not necessarily capture DTs exclusively (DeYoung, 2015). For example, asking persons to rate themselves on items that are supposed to measure a given trait (e.g., extraversion)

yields, to be precise, scores on generalized and explicit self-concepts related to that trait domain.

A related limitation of the DT–CA differentiation is that some DTs are assessed using words involving interests, such as “I enjoy” or “I like”. Moreover, response tendencies and socially desirable responding may be heritable to some degree. Consequently, each characteristic measured with self-reports would appear to be more or less heritable, even though the characteristic is not heritable. This confounding in measures of DTs and CAs can explain the rather smaller—though statistically significant—differences in environmentality that could be expected to be larger when this method confounding is controlled for. One solution might be to use multivariate cross-contextual modeling strategies for disentangling method (e.g., self-rating) specificity from valid trait and adaptation components in measures of DTs and CAs. This could test to what extent DT measures in fact represented traits and CA measures indeed reflected the adaptations they should capture (Kandler & Rauthmann, 2022). Consequently, measures of personality characteristics could reflect both DTs and CAs to different degrees. To what extent a measure is more trait-like (i.e., consistent across situations and contexts) or more adaptation-like (i.e., stable but context-dependent) is in fact an empirically answerable question.

Although we were able to model one kind of gene–environment interplay (i.e., the passive type) with the use of an extended twin family model, there are other forms of transactions and interactions between genetic and environmental factors which could not be modeled but could drive the development of personality differences (see Kandler, Zapko-Willmes, et al., 2021, for an overview). If, for example, active and evocative kinds of gene–environment transactions are relevant but not modeled, their contributions would be confounded with estimates of contributions of additive genetic sources. However, if interactions between genetic factors and environmental factors not shared by twins are important but not modeled, their contribution would be confounded with estimates of nonshared environmental contributions. If these gene–environment transactions and interactions differed in their contributions to DTs and CAs, then the larger additive genetic component and the smaller nonshared environmental component in DTs compared to CAs, as was found in our study, would be attributable to those mechanisms.

The contributions and the interplay of genetic and environmental influences on individual differences in personality characteristics can slightly shift across the lifespan (Kandler, Bratko, et al., 2021; Kandler, Zapko-Willmes, et al., 2021). This, in addition to other factors and processes, may lead to differential expressions of the same characteristic in different ages, a phenomenon known as heterotypic continuity. The ETFD is based on

the assumption that the measures used reflect the characteristic similarly for all members of a family across generations and ages. Although we could establish metric MI across family members (i.e., same loadings of items) for most measures and even scalar MI (i.e., same intercept of items) for some of them indicating low variance in the actual meaning of items, developmental research has shown that many constructs can change in other forms of expression with age (Petersen et al., 2020), such as age-related increasing or decreasing variance and rank-order stability. Environmentalit may be crucial to consider in those aspects of heterotypic continuity, because age-related experiences can lead to different behavioral manifestations of the same psychological characteristic at different ages. Thus, it could be an interesting avenue for future longitudinal studies on environmentalit of DTs and CAs to address this phenomenon.

A further limitation is that we did not measure environmental influences directly but estimated different environmental components as non-genetic sources of variance between and as covariance within family and non-family members. Thus, we cannot know which specific environmental factors drive the larger twin differences in CAs than in their DTs, or which spouse-specific factors act to increase spouse similarity more so in CAs than in DTs. Our study provided hints toward which relevant environmental factors to look for—those that act to increase twin differences (e.g., individual life events) and spouse similarity (e.g., spouse interaction). Future studies may directly measure and test these potentially relevant environmental factors which are more relevant for CAs.

Lastly, the focus of the current paper was directed at the comparison of environmentalit between DT and CA measures. A next step for future research might be to look at the common and specific environmental as well as genetic variance components across DT and CA measures to test further relevant questions, such as to what extent genetic and environmental differences in DTs can account for the genetic and environmental variance in CAs, or to what extent genetic and environmental components are specific to CAs.

## 5 | CONCLUSION

Our results provide support for the differentiation of personality characteristics into DTs and CAs. The relatively higher environmentalit of CA measures indicates that these characteristics may be more susceptible to contextual influences as proposed in several theoretical models (McAdams & Pals, 2006; McCrae & Costa, 2008). The relatively higher heritability of DTs and no differences between DT domains and facets provide further support for a primary genetic architecture underlying the hierarchical structure

of trait models (McCrae et al., 2001; Yamagata et al., 2006). Furthermore, our findings suggest that individual-specific factors and spouses or partners may play important roles for the higher environmentalit of CAs. This is consistent with their assumed relatively larger specificity in relation to individuals' particular life circumstances (DeYoung, 2015; McAdams, 2015). In sum, our findings are in line with the notion by Bleidorn et al. (2010) that “a comprehensive understanding of personality function and development requires a detailed consideration of the full range of elements relevant to the personality system in order to exploit their separate as well as their joint contributions to the way individuals shape their lives” (p. 377).

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest.

## ETHICS APPROVAL

This project has been approved by local ethics committees.

## OPEN SCIENCE STATEMENTS

Data are available as Scientific Use File via the project's homepage: <http://www.speady.de/studies/?lang=en>. The current study was preregistered with an analysis plan at the open science framework: <https://osf.io/q6tru>. All data analytic scripts, codes, reduced anonymized input data files for twin family model analyses as well as additional material are openly available: <https://osf.io/qfch5/>.

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## ENDNOTES

- <sup>1</sup> We use the term *broad-sense environmental sources* for the sum of all environmental influences contributing to personality differences, whereas *narrower environmental sources* are meant in the sense of specific environmental influences, such as those shared by all members of a family, by only a few persons (e.g., siblings or spouses), or those generally not shared by individuals.



- <sup>2</sup> Heritability is defined as variance component in characteristics attributable to genetic differences.
- <sup>3</sup> Every measure harbored state, adaptation, and trait variance (Kandler & Rauthmann, 2022), but participants were asked in all instances to rate enduring characteristics which should have increased trait and adaptation variance relative to state variance. Further, technically, all self-report measures tapped participants' explicit self-concepts, but these concepts refer to different conceptual and content domains (e.g., basic traits, interests, goals, etc.). We also note that for many of the constructs assessed, self-reports are a viable way of assessing them (e.g., self-esteem, self-efficacy, and values).
- <sup>4</sup> We also preregistered a third hypothesis which goes beyond the focus of the current study.
- <sup>5</sup> The SPeADy data are available as pseudonymized Scientific Use File via the SPeADy homepage: <http://www.speady.de/studies/?lang=en>.

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