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Genetic and Environmental Factors of Non-Ability-Based Confidence

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Abstract

Non-ability-based confidence is confidence in one's ability that is not calibrated to actual ability. Here, we examine what psychological factors are associated with possessing more or less confidence relative to one's ability and to what extent genetic and environmental processes contribute to these links. Using data from the Texas Twin Project (*N* = 1,588 participants, aged 7–15 years), we apply a latent variable residual approach to calculate non-ability-based confidence as self-rated confidence net of ability on standardized cognitive tests. Non-ability-based confidence was modestly heritable (9%–28%) and strongly positively correlated with the need for cognition, mastery goal orientation, grit, openness, and emotional stability. These correlations were partly mediated by genetic factors (57% of the association on average). This widespread pattern of associations between non-ability-based confidence and several other measures of thinking, feeling, and acting suggest that non-ability-based confidence can be conceptualized as a personality attribute.

Keywords

non-ability-based confidence, overconfidence, confidence, behavior genetics, personality, cognitive ability

Humans are often inaccurate in their perceptions of their ability. Sometimes, we believe that we are more skilled than our abilities would suggest. An overconfident individual might attempt to (poorly) explain a subfield of study to an expert, or they might attempt to parallel park in a space too small for their vehicle. Here, confidence in domain knowledge or driving skill might outstrip actual ability. Other times, we believe that we are less skilled than our abilities would suggest. An underconfident individual might forgo speaking up at a conference even though they are the expert, or they may choose to only park in an empty parking lot. Confidence not calibrated to ability is non-ability-based confidence.

Non-ability-based confidence is part of a family of confidence judgments including overconfidence in the social psychology (Moore & Healy, 2008) and economics (Biais et al., 2005; Glaser & Weber, 2007; Malmendier & Tate, 2008) literatures, and metacognitive calibration accuracy in the educational psychology literature (Schraw, 2009), all of which describe the discrepancy between confidence and ability. Although much is known about *when* people tend to be overconfident (i.e., across many domains from intelligence to job performance to friendliness; Alicke et al., 1995; Harrison & Shaffer, 1994), less is known about *who* tends to be overconfident.

We use a genetically informed sample of children to explore a variety of academically relevant psychological factors that may predict which children have positive levels of non-ability-based confidence (assessed in the domain of cognitive ability) and are overconfident and which children have negative levels of non-ability-based confidence and are underconfident. We then estimate the genetic and environmental factors of non-ability-based confidence to further understand how non-ability-based confidence develops.

Why Is Non-Ability-Based Confidence Important?

Across the social psychology, economics, and education literatures, both positive and negative consequences of high non-ability-based confidence, or overconfidence, have been identified. From the social and economic literatures, non-ability-based confidence has interpersonal advantages (e.g., prestige, romantic success; Anderson et al., 2012; Murphy et al., 2015) and societal disadvantages (e.g., large-scale warfare, investment bubbles, costly litigation;

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Abbes, 2012; Camerer & Lovallo, 1999; Johnson, 2004). In the educational psychology literature, being overconfident may put students in situations where they can learn (e.g., taking a harder math class; Marsh et al., 2005). On the other hand, overconfident individuals may fail to recognize what they still need to learn (e.g., understudying; Hacker et al., 2008).

Confidence, over and above accuracy (i.e., non-ability-based confidence), has been shown to have significant predictive validity for intelligence and achievement test scores (Stankov & Lee, 2008). In a review of the literature, Stankov (2013) identified confidence as one of the best noncognitive predictors of such outcomes. Confidence net of ability outperforms self-efficacy, self-concept, and anxiety in the prediction of school grades in teenagers (Stankov et al., 2012). Together, this work suggests that whether an individual is high or low in non-ability-based confidence is consequential for their educational, financial, and social outcomes. Thus, understanding who displays high or low non-ability-based confidence is an important area of research. To advance this area of work, we provide a portrait of individuals with non-ability-based confidence by testing for associations with a range of academically relevant characteristics.

Does Non-Ability-Based Confidence Correlate With Cognition, Big Five Personality, or Character Skills?

Cognition. Perhaps unintuitively, one factor that might contribute to the scale of non-ability-based confidence might be ability: People who are very low (or very high) in their ability have more room to over- (or under-) estimate that ability such that lower ability people are more likely to be overconfident. In keeping with this idea, early work by Kruger and Dunning (1999) showed that individuals who were unskilled, or low in ability, were the ones most likely to inflate their self-estimates of ability or confidence. We extend this work to investigate whether individuals who are high in one type of ability relative to another, a characteristic know as tilt (Park et al., 2007), are also higher in non-ability-based confidence. Perhaps individuals who know that they excel in certain achievement situations anchor their confidence to their best performance domain. They may extrapolate from their superior performance in one specific domain and assume that they have superior performance in all domains when, in fact, they do not. On the other hand, it could be that achievement in one domain does not influence confidence in the other domain (Marsh et al., 2015), which would suggest that individuals who tilt toward one domain would not exhibit non-ability-based confidence in their nontilt domain.

Big Five personality. Extraverted, agreeable, and conscientious people tend to have higher levels of overconfidence (Bashir et al., 2013; Dahl et al., 2010; Pallier et al., 2002; Schaefer et al., 2004), although null and negative associations have also been found (Anderson et al., 2012; Dahl et al., 2010). Openness has been found to be strongly positively correlated (Bashir et al., 2013) or null to slightly negative (Anderson et al., 2012; Dahl et al., 2010; Schaefer et al., 2004). Finally, emotional stability tends to be uncorrelated with overconfidence (Anderson et al., 2012; Bashir et al., 2013; Dahl et al., 2010; Schaefer et al., 2004). These studies have typically used small sample sizes and different conceptualizations of overconfidence (e.g., equating risk-taking to overconfidence, only analyzing confidence as compared to confidence net of ability as we do here), which may account for the inconsistent findings.

Character skills. We expand the scope of psychological correlates associated with non-ability-based confidence to academically relevant personality traits (sometimes referred to as character, noncognitive skills, or socioemotional skills; Tucker-Drob et al., 2016). For example, we expect that children who are high in need for cognition, the tendency to think deeply about and evaluate information (Cacioppo & Petty, 1982), to have high confidence in their abilities (Luong et al., 2017). We similarly expect that children high in grit, the tendency to be passionate about learning and achieving and to persevere even in the face of failure (Duckworth et al., 2007), to be confident. Because of this desire to keep working and keep trying, these children may be less bothered by situations in which their confidence outpaces their abilities. Children with a mastery goal orientation may be similarly likely to enter into challenging situations in order to fulfill their desire to learn and develop their abilities (Ames & Archer, 1988; Pintrich, 2000). In doing so, they may develop high self-confidence (Coutinho & Neuman, 2008; Kleitman & Gibson, 2011) which will extend beyond the realities of the individuals' abilities.

To What Extent Might Genetic and Environmental Factors Play a Role in Non-Ability-Based Confidence?

In addition to testing correlates, we decompose the variance in non-ability-based confidence into genetic and environmental components. Previous research has shown that ability and confidence have both genetic and environmental factors. Confidence is between 15% and 30% heritable (Tucker-Drob et al., 2016), and ability is between 50% and 70% heritable (Tucker-Drob et al., 2013). To our knowledge, only one study has estimated the heritability of non-ability-based confidence. In a study of 440 twin pairs, Cesarini and colleagues (2009) found heritability estimates between 16% and 34%. This study was conducted with adults and focused solely on non-ability-based confidence. In the current article, we replicate this work in a substantially larger sample ($N = 814$) of twin/triplet pairs and extend it by examining the genetic and environmental factors connecting non-ability-based confidence and psychological characteristics.

Present Study

In the present study, we used a genetically informed sample to investigate the extent to which genetic and environmental factors play a role in non-ability-based confidence in the domain of cognitive ability. We ask four research questions:

1. Can we specify a structural model to measure non-ability-based confidence?
2. What psychological variables correlate with non-ability-based confidence?
3. To what extent do genetic and environmental sources of variance play a role in non-ability-based confidence?
4. Do the links between non-ability-based confidence and psychological variables emerge due to genetic or environmental processes?

Method

Participants

Data were drawn from an ethnically and socioeconomically diverse population-based sample from the Texas Twin Project, an ongoing project with recruitment in the Austin, TX, area (Harden et al., 2013). The sample includes 1,588 third- to eighth-grade twins and triplets (763 girls), comprising a total of 814 sibling pairs (MZ = 270 pairs, DZ = 544 pairs). Participants ranged in age from 7.80 to 15.25 years ($M = 10.94$ years, $SD = 1.79$); 62% of children were non-Hispanic White, 13% were Hispanic/Latino, 5% were Black/African American, 4% were East Asian/Pacific Islander, and 16% were multiple race/ethnicity categories or other. Based on our sample size, we had excellent statistical power for our primary analyses (see Supplementary Materials for full power analysis).

Measures

Confidence. Children were asked about their self-perceived intellectual ability. They rated how competent, smart, and capable of learning they considered themselves to be using the six-item Intellectual Investment subscale of the Multidimensional Achievement-Relevant Personality Scale (Briley et al., 2014) and a single item "I am smart." These items were assessed on a 5-point Likert-type scale.

Ability. Because our confidence measure was not tied to a specific domain of achievement, we constructed multiple ability factors using the following tests. We did not have an a priori hypothesis about which of these latent ability factors was the most appropriate match for the confidence factor.

Crystallized knowledge. This study measured mathematics achievement with the calculations test and reading achievement with the passage comprehension test, both from the Woodcock–Johnson Tests of Achievement–III (Woodcock, McGrew, & Mather, 2001), and verbal knowledge with the vocabulary and similarities tests from the Wechsler Abbreviated Scale of Intelligence, second edition (WASI-II; Wechsler, 2011).

Fluid intelligence. This study measured fluid intelligence with the matrix reasoning and block design subtests of the WASI-II (Wechsler, 2011) and the spatial relations subtest from the Woodcock–Johnson Tests of Cognitive Abilities–III (Woodcock, Mather, & McGrew, 2001).

Processing speed.. This study measured processing speed with the letter comparison (Salthouse & Babcock, 1991), pattern comparison (Salthouse & Babcock, 1991), and symbol search (Wechsler, 2003) tests.

Zygosity. Zygosity was determined by latent class analysis (entropy = .98) using the ratings of parents and two trained research assistants on the physical similarity of the twins/triplets (e.g., hair texture, eye color), whether others tend to confuse the twins in photographs, and whether they are as alike as two peas in a pod. This approach to determining zygosity has been found to be highly accurate when compared to genotyping (Heath et al., 2003). In a subsample of the Texas Twin Project ($n = 438$ same-sex twin pairs), the latent class analysis zygosity classification was 94% accurate as verified via genotyping.

Psychological correlates. For a full description of the psychological correlates measured along with example items, please see the Supplemental Material. Table 1 provides a brief overview of the measures.

Analytic Approach

First, we constructed our non-ability-based confidence variable. We operationalized non-ability-based confidence as the extent to which children's self-perceptions of intellectual ability (confidence) differ from their assessed intellectual ability/achievement. Our operationalization uses similar logic as the original economic conceptualization of noncognitive skills as residual variation in attainments not due to measured cognitive ability (Heckman et al., 2006; Heckman & Rubinstein, 2001). We used a latent residual score model in which non-ability-based confidence was identified by regressing confidence on ability, creating a latent factor representing residual variance in confidence with a loading of 1 on confidence and fixing the residual variance of confidence to 0 (see Figure 1, Box 1). The latent confidence factor was identified by seven self-report items combined into three parcels to reduce model complexity (Rhemtulla, 2016). The latent ability factor was identified by three or four standardized tests, depending on which variant of ability was used. By taking this approach, we more robustly assess confidence and ability (Murphy et al., 2017), minimize weak measurement (Westfall & Yarkoni, 2016), and separate nonshared environmental variance from random measurement error.

We created three iterations of the non-ability-based confidence variable, one for each of the ability variables (see Supplemental Table S3 for fit statistics). As an exploratory analysis that was not included in our preregistration, we also

Table 1. List of Psychological Correlates With Measures and Reliabilities.

Psychological Correlate	Measure	Reliability
Openness	Child version of the Big Five Inventory (John et al., 2008)	.664
Conscientiousness	Child version of the Big Five Inventory (John et al., 2008)	.753
Extroversion	Child version of the Big Five Inventory (John et al., 2008)	.740
Agreeableness	Child version of the Big Five Inventory (John et al., 2008)	.706
Emotional stability	Child version of the Big Five Inventory (John et al., 2008)	.667
Need for cognition	Need for Cognition Scale (Kokis et al., 2002)	.717
Mindset	Mindset Scale (Dweck, 2000)	.843
Grit	Grit Scale for Children (Duckworth & Quinn, 2009)	.666
Educational attitudes	Skepticism about the Relevance of School for Future Success Scale from the Patterns of Adaptive Learning Scales (Midgley et al., 2000)	.768
Mastery goal orientation	Mastery Goal Orientation (Revised) Scale from the Patterns of Adaptive Learning Scales (Midgley et al., 2000)	.802
Performance approach	Performance approach items from the Patterns of Adaptive Learning Scales (Midgley et al., 2000)	.844
Performance avoidance	Performance avoidance items from the Patterns of Adaptive Learning Scales (Midgley et al., 2000)	.590
Math − reading tilt	Math score − reading score	—
Crystallized − fluid tilt	Crystallized knowledge score − fluid intelligence score	—
Processing speed − crystallized tilt	Processing speed score speed − crystallized knowledge score	—
Processing speed − fluid tilt	Processing speed score speed – fluid intelligence score	—
Math − reading tilt^2	(Math score − reading score)^2	—
Crystallized − fluid tilt^2	(Crystallized knowledge score − fluid intelligence score)^2	—
Processing speed − crystallized tilt^2	(Processing speed score speed – crystallized knowledge score)^2	—
Processing speed − fluid tilt^2	(Processing speed score speed − fluid intelligence score)^2	—

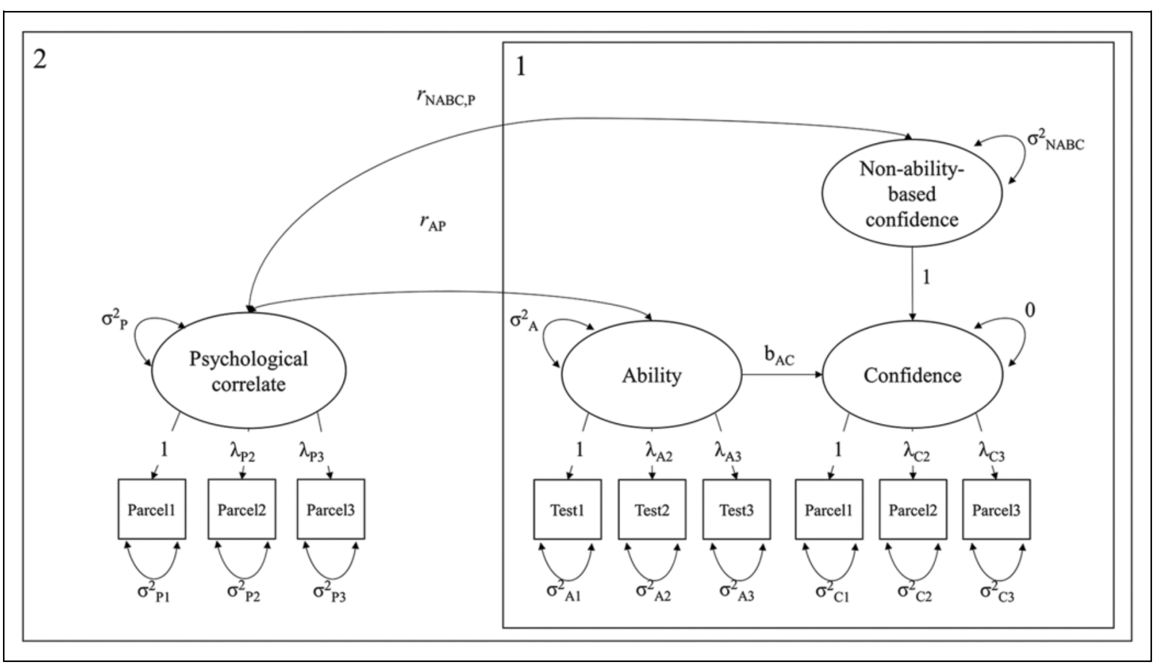

Figure 1. Box 1 (which corresponds to Step 1 of our analysis plan) depicts the generic latent residual score model of the non-ability-based confidence model that we fit for all three iterations of ability (crystallized knowledge, fluid intelligence, and processing speed). Box 2 (which corresponds to Step 2 of our analysis plan) depicts the phenotypic correlation model that we fit for all three iterations of ability with the psychological correlates.

created a fourth iteration of non-ability-based confidence in which all three ability types were included in the same model as simultaneous predictors of confidence. In this additional model, we correlated the ability types with each other. Positive (negative) non-ability-based confidence scores indicate that the individual has a higher (lower) level of confidence compared to

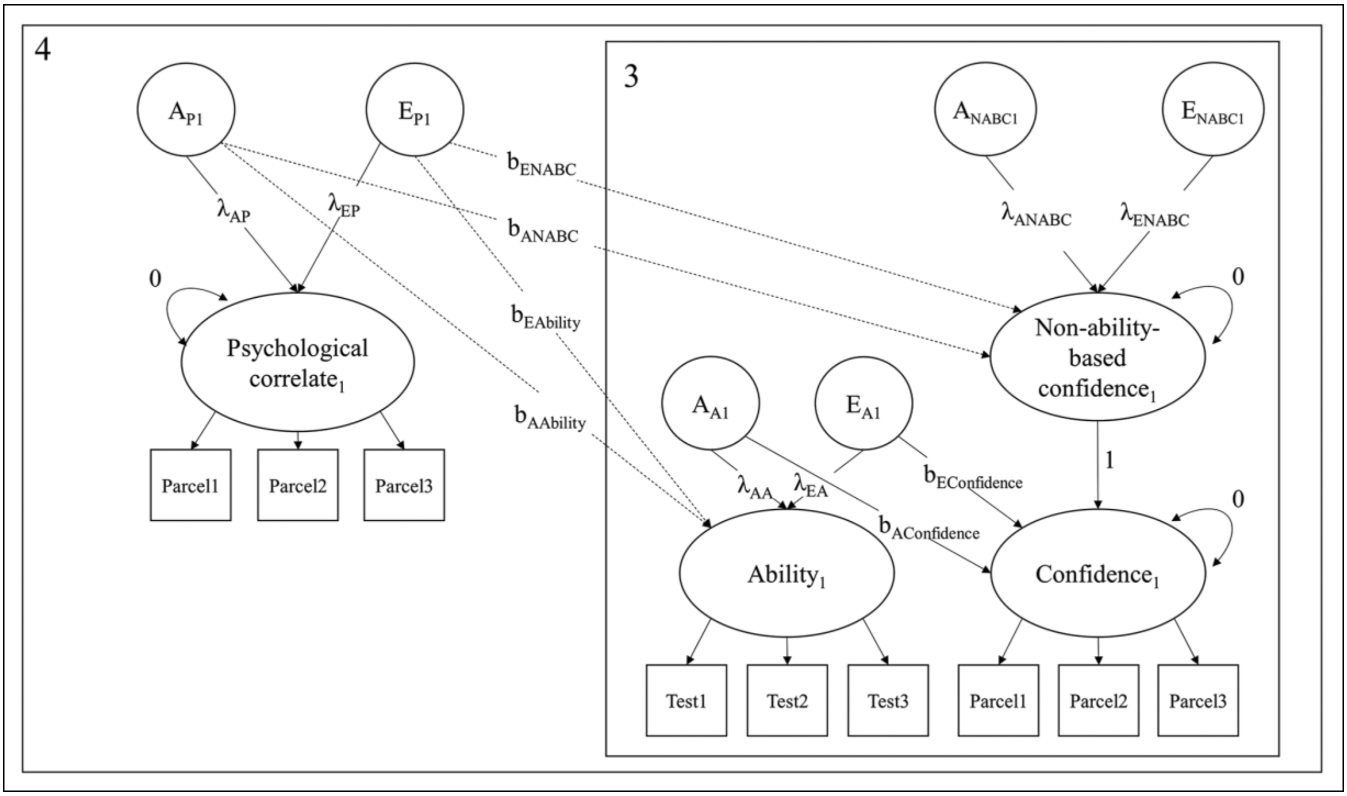

Figure 2. Box 3 (which corresponds to Step 3 of our analysis plan) depicts the AE model for non-ability-based confidence. In this model, the variance in non-ability-based confidence and ability is decomposed into its A and E components. In addition, instead of the direct regression of confidence on ability, as it is in Figure 1, Box 1, the regression operates through the A and E factors of ability in this model. The latent additive genetic (A) factors (for the psychological correlate, ability, and non-ability-based confidence) are correlated at 1.0 for monozygotic twins and 0.5 for dizygotic twins. In addition, we correlated the manifest ability, confidence, and psychological correlate items across twins. Box 4 (which corresponds to Step 4 of our analysis plan) depicts the full model that investigates the bivariate heritability and environmentality of the correlation between non-ability-based confidence and psychological correlates. The dotted lines represent the cross pathways from the A and E latent variables of the psychological correlate to the non-ability-based confidence and ability factors of the non-ability-based confidence models. To determine the genetic contribution to the correlation between the psychological correlate and non-ability-based confidence, we multiply λ_{AP} and b_{ANABC}, and to determine the environmental contribution to the correlation, we multiply λ_{EP} and b_{ENABC}. C = shared environmental factors; E = nonshared environmental factors.

similarly achieving peers. Because we did not have an a priori hypothesis about which specific ability measure best matches the confidence measure, all subsequent analyses were performed for each iteration of non-ability-based confidence.

Second, we extended the model to include potential correlates using a similar latent factor approach (see Figure 1, Box 2). We used parcels in identifying the latent psychological correlates in order to reduce model complexity. Because we conducted many tests, we focus on effect size estimation rather than *p* values in interpreting our results.

Third, we investigated the genetic and environmental influences on non-ability-based confidence and all psychological correlates (see Supplementary Materials, Table S1). We follow standardized procedures for fitting the classical twin design (Neale & Cardon, 1992). The online supplement provides a short tutorial on the approach for unfamiliar readers. Briefly, variance in non-ability-based confidence was decomposed into additive genetic (A), shared environmental (C), and nonshared environmental (E) components. The shared environment includes influences that lead siblings growing up in the same home to be similar, and the nonshared environment includes influences that differentiate siblings growing up in the same home, after taking into account genetic differences. The nonshared environment can include factors that are objectively shared among the twins (e.g., same parents/home environment or same teacher/school environment) but are experienced differently by each twin (e.g., different treatment by parents or teachers). For most variables, including all versions of non-ability-based confidence (see Kovas et al., 2015 for similar results), a model including only AE factors did not fit significantly worse than a model with ACE factors. The more parsimonious model was retained (see Supplemental Table S1 for fit statistics). Figure 2 provides a graphical representation of the model.

Fourth, we determined the proportion of the correlation between non-ability-based confidence and the psychological

Table 2. Phenotypic Correlations Between Non-ability-based Confidence and Psychological Correlates.

	Non-Ability-Based Confidence			
Psychological Correlate	Crystallized Knowledge	Fluid Intelligence	Processing Speed	All Ability Types
Openness	.393 (.038)	.447 (.038)	.477 (.038)	.419 (.039)
Conscientiousness	.240 (.041)	.253 (.040)	.241 (.041)	.230 (.041)
Extroversion	.196 (.043)	.211 (.042)	.192 (.042)	.181 (.043)
Agreeableness	.020 (.041)	.042 (.041)	.053 (.041)	.026 (.041)
Emotional stability	.346 (.038)	.350 (.038)	.347 (.038)	.343 (.038)
Need for cognition	.524 (.034)	.587 (.034)	.564 (.033)	.505 (.034)
Mindset	.119 (.037)	.160 (.037)	.148 (.037)	.109 (.037)
Grit	.369 (.042)	.397 (.041)	.386 (.042)	.356 (.042)
Mastery goal orientation	.410 (.040)	.418 (.041)	.408 (.041)	.397 (.041)
Performance approach	.217 (.037)	.188 (.038)	.189 (.037)	.217 (.037)
Performance avoidance	.163 (.049)	.144 (.048)	.168 (.047)	.182 (.049)
Educational attitudes	.157 (.045)	.212 (.045)	.206 (.045)	.149 (.045)
Math − reading tilt	—	−.070 (.037)	−.084 (.037)	—
Crystallized − fluid tilt	−.005 (.046)	.267 (.038)	.143 (.048)	—
Processing speed − crystallized tilt	.135 (.029)	−.018 (.036)	−.209 (.031)	—
Processing speed − fluid tilt	.078 (.048)	.134 (.037)	−.139 (.042)	—
Math − reading tilt^2	.044 (.032)	.043 (.033)	.030 (.032)	.038 (.033)
Crystallized − fluid tilt^2	.031 (.051)	−.001 (.060)	−.011 (.053)	.045 (.050)
Processing speed − crystallized tilt^2	.035 (.033)	.006 (.035)	.002 (.040)	.000 (.036)
Processing speed − fluid tilt^2	.004 (.049)	.023 (.048)	.011 (.051)	−.003 (.048)

Note. Correlations are reported with standard errors in parentheses. Cells marked with a dash did not converge.

correlate that was attributable to genetic and environmental factors. To do this, we combined the univariate AE models from the previous steps and then regressed non-ability-based confidence and ability onto the A and E latent factors of the psychological correlates (see Figure 2, Box 4).

All models, including phenotypic models, are controlled for centered-age, centered-age^2, sex, and age × sex at the indicator level. This approach is standard in behavior genetic models (McGue & Bouchard, 1984). All analyses were conducted using Mplus Version 8.1 using cluster robust standard errors to correct for family structure (Muthén & Muthén, 1998).

Results

Our preregistered analysis plan (https://osf.io/a2syd) and example analytic code (https://osf.io/mxgre) can be found on the Open Science Framework. Interested researchers may contact the directors of the Texas Twin Project for information on obtaining the data (longhorntwins.com).

Phenotypic Correlations

The correlation between the latent confidence factor and the latent ability factors, before being put into the non-ability-based confidence models, was .162 for fluid intelligence, .242 for processing speed, and .300 for crystallized knowledge (ps < .001). While confidence and ability are significantly correlated, they are not perfectly correlated, suggesting that much of the variance in confidence is not explained by ability.

The correlations between non-ability-based confidence, using each of the three ability types and the model including all ability types simultaneously, with the psychological variables are reported in Table 2. All models fit well with comparative fit indexes (CFIs) greater than .966 (see Table S3 in Supplemental Materials). Across the four iterations of non-ability-based confidence, a similar pattern emerged. Non-ability-based confidence was moderately to strongly associated with openness (r = .393–.477), emotional stability (r = .343–.350), need for cognition (r = .505–.587), grit (r = .356–.397), and mastery goal orientation (r = .397–.418). This result implies that children who are open to new experiences, not anxious or depressed, enjoy thinking deeply about problems, and want to master concepts are likely to have high levels of non-ability-based confidence.

In addition, non-ability-based confidence was moderately associated with conscientiousness (r = .230–.253), extroversion (r = .181–.211), growth mindset (r = .109–.160), performance approach orientation (r = .188–.217), performance avoid orientation (r = .144–.168), and educational attitudes (r = .149–.212). The only psychological correlate that did not significantly correlate with non-ability-based confidence was agreeableness (r = .020–.053). Some of the tilt variables were significantly correlated with non-ability-based confidence, but on the whole, ability tilt and tilt^2 were not substantial correlates of non-ability-based confidence (see Supplementary Materials for more details).[1]

Genetic and Environmental Decomposition of Non-Ability-Based Confidence

The AE decompositions of non-ability-based confidence are presented in Table 3. When the ability component was

Table 3. ACE (AE) Decomposition of Non-Ability-Based Confidence.

Non-Ability-Based Confidence	λ_{ANABC} (*SE*)	λ_{ENABC} (*SE*)	a^2	e^2	λ_{AA} (*SE*)	λ_{CA} (*SE*)	λ_{EA} (*SE*)	$b_{AConfidence}$ (*SE*)	$b_{CConfidence}$ (*SE*)	$b_{EConfidence}$ (*SE*)
Crystallized knowledge	.401 (.915)	.823 (.046)	.192	.808	.696 (.076)	.606 (.074)	.386 (.043)	.394 (.174)	.087 (.114)	.012 (.152)
Fluid intelligence	.516 (.076)	.837 (.048)	.275	.725	.950 (.023)	—	.312 (.070)	.170 (.051)	—	.067 (.134)
Processing speed	.494 (.156)	.839 (.088)	.257	.743	.880 (.058)	—	.475 (.107)	.218 (.055)	—	.060 (.080)
All ability types	.385 (.397)	.818 (.052)	.182	.818	[a]	[a]	[a]	[a]	[a]	[a]

Note. λ_{ANABC} refers to the genetic component of non-ability-based confidence. λ_{ENABC} refers to the nonshared environmental component of non-ability-based confidence. a^2 is the standardized proportion of variance attributable to A for non-ability-based confidence. e^2 is the standardized proportion of variance attributable to E for non-ability-based confidence. λ_{AA} refers to the genetic component of ability. λ_{CA} refers to the shared environmental component of ability. λ_{EA} refers to the nonshared environmental component of ability. $b_{AConfidence}$ refers to the regression of confidence on the A component of ability. $b_{EConfidence}$ refers to the regression of confidence on the E component of ability. A refers to genetic factors. C refers to shared environmental factors. E refers to nonshared environmental factors.

[a]Because the fourth iteration of non-ability-based confidence uses all three ability types, there are many additional pathways that are not reported here because of space constraints. The full table of pathways from the model can be found in the Supplementary Materials, Table S2.

identified by crystallized knowledge, 15.2%, 3.4%, and 81.4% of the variance in non-ability-based confidence was attributable to genetic, shared environmental, and nonshared environmental factors, respectively. When the shared environmental component was dropped, 19.2% and 80.8% of the variance in non-ability-based confidence was attributable to genetic and nonshared environmental factors, respectively. We dropped the shared environmental component based on model comparisons between the ACE and AE models. A $\Delta\chi^2$ test indicated that the AE model did not fit significantly differently than the ACE model, and thus, because the AE model was more parsimonious, it was chosen as the preferred model for each variant of non-ability-based confidence. Model fit statistics for all variables can be found in Table S4 of the Supplementary Materials. All selected models fit well with CFIs greater than .910.

The pattern was similar for the other two ability types. In non-ability-based confidence as defined by fluid intelligence, 17% of the variance was attributable to genetic factors (which becomes 27.5% after dropping C), 8% was attributable to shared environmental factors, and 75% was attributable to nonshared environmental factors (72.5% after dropping C). For non-ability-based confidence with processing speed as the ability type, 15.4% of the variance was attributable to genetic factors (25.7% after dropping C), 7.8% was attributable to shared environmental factors, and 76.8% was attributable to nonshared environmental factors (74.3% after dropping C). Finally, for non-ability-based confidence with all three ability types in the model, 8.9% of the variance is attributable to genetic factors (18.2% after dropping C), 6.9% is attributable to shared environmental factors, and 84.2% is attributable to nonshared environmental factors (81.8% after dropping C). This result implies that, after taking into account their objectively measured cognitive skills, most of the variation in children's confidence in their own abilities is due to idiosyncratic, person-specific environmental experiences rather than the systematic effects of family background or heritable personality traits.

Genetic and Environmental Contributions to the Relation Between Non-Ability-Based Confidence and Psychological Correlates

Across all versions of non-ability-based confidence, grit, mastery goal orientation, need for cognition, emotional stability, and openness had statistically significant genetic and environmental associations with non-ability-based confidence. Conscientiousness, extroversion, and educational attitudes had significant genetic associations only, and mindset, performance approach, and performance avoidance had significant environmental associations only. The genetic and environmental associations were nonsignificant for all other variables with the four iterations of non-ability-based confidence. Supplemental Tables S5 and S6 report full standardized parameter estimates. Here, we focus on the effect size estimates of genetic and environmental contributions to the phenotypic correlation (i.e., in correlation units, how much of the phenotypic correlation is attributable to genetic or environmental effects) and the proportion of the phenotypic correlation attributable to genetic or environmental effects. All bivariate models between the psychological correlate and crystallized knowledge, fluid intelligence, and processing speed as the singular ability type in non-ability-based confidence fit well with CFIs greater than .953. The models where ability is identified by all three ability types in the same model fit slightly less well with CFIs above .898.

For most of the psychological correlates, the correlation with non-ability-based confidence was partially attributable to genetic factors and partially attributable to environmental factors. On average, 57% of the correlation was attributable to genetic factors, and 43% was attributable to nonshared environmental factors. For some of the variables, the proportion attributable to genetic effects was above 100% while the proportion attributable to environmental effects was negative (e.g., agreeableness) due to the direction of the genetic and environmental associations being opposite. If we omit these variables, 52% of the correlation was attributable to genetic factors, and 48% was attributable to nonshared environmental

Table 4. A and E Contribution and Bivariate Heritability and Environmentality of Non-Ability-Based Confidence With Psychological Correlates.

Psychological Correlate	Genetic Contribution	Environmental Contribution	Proportion Genetic	Proportion Environmental
Non-ability-based confidence (fluid intelligence) with				
Openness	.279	.294	0.487	0.513
Conscientiousness	.150	.105	0.589	0.411
Extroversion	.167	.053	0.758	0.242
Agreeableness	.059	−.017	1.402	−0.402
Emotional stability	.124	.258	0.325	0.675
Need for cognition	.465	.310	0.600	0.400
Mindset	.064	.114	0.360	0.640
Grit	.247	.158	0.610	0.390
Educational attitudes	.223	.003	0.986	0.014
Mastery goal orientation	.217	.231	0.484	0.516
Performance approach	.011	.167	0.062	0.938
Performance avoidance	−.026	.208	−0.141	1.141
Math − reading tilt	−.010	−.058	0.153	0.847
Crystallized − fluid tilt	Model did not converge			
Processing speed − crystallized tilt	−.055	−.010	0.841	0.189
Processing speed − fluid tilt	Model did not converge			
Math − reading tilt^2	.003	.014	0.175	0.825
Crystallized − fluid tilt^2	.017	−.042	−0.679	1.679
Processing speed − crystallized tilt^2	−.053	.037	3.248	−2.248
Processing speed − fluid tilt^2	.036	−.034	18.706	−17.706
Non-ability-based confidence (crystallized knowledge) with				
Openness	.282	.294	0.490	0.510
Conscientiousness	.151	.110	0.578	0.422
Extroversion	.172	.054	0.759	0.241
Agreeableness	.058	−.008	1.171	−0.171
Emotional stability	.135	.251	0.350	0.650
Need for cognition	.466	.313	0.598	0.402
Mindset	.070	.109	0.392	0.608
Grit	.246	.164	0.601	0.399
Educational attitudes	.232	.002	0.990	0.010
Mastery goal orientation	.217	.235	0.480	0.520
Performance approach	.020	.157	0.115	0.885
Performance avoidance	.000	.188	0.000	1.000
Math − reading tilt	Model did not converge			
Crystallized − fluid tilt	.100	−.011	1.118	−0.118
Processing speed − crystallized tilt	−.078	−.020	0.799	0.201
Processing speed − fluid tilt	−0.042	−.045	0.481	0.519
Math − reading tilt^2	.003	.008	0.278	0.722
Crystallized − fluid tilt^2	.007	−.062	−0.133	1.133
Processing speed − crystallized tilt^2	−.052	.030	2.295	−1.295
Processing speed − fluid tilt^2	.012	−.019	−1.728	2.728
Non-ability-based confidence (processing speed) with				
Openness	.272	.308	0.469	0.531
Conscientiousness	.156	.103	0.601	0.399
Extroversion	.172	.049	0.777	0.223
Agreeableness	.056	−.015	1.375	−0.375
Emotional stability	.124	.261	0.321	0.679
Need for cognition	.461	.315	0.594	0.406
Mindset	.069	.109	0.388	0.612
Grit	.237	.168	0.585	0.415
Educational attitudes	.217	.009	0.961	0.039
Mastery goal orientation	.214	.237	0.474	0.526
Performance approach	.015	.164	0.084	0.916
Performance avoidance	−.017	.202	−0.093	1.093
Math − reading tilt	−.008	−.044	0.155	0.845
Crystallized − fluid tilt	.092	−.022	1.311	−0.311
Processing speed − crystallized tilt	−.008	−.004	0.651	0.349

(continued)

Table 4. (continued)

Psychological Correlate	Genetic Contribution	Environmental Contribution	Proportion Genetic	Proportion Environmental
Processing speed − fluid tilt	−.072	−.001	0.989	0.011
Math − reading tilt^2	.007	.008	0.468	0.532
Crystallized − fluid tilt^2	−.009	−.029	0.240	0.760
Processing speed − crystallized tilt^2	−.063	.041	2.868	−1.868
Processing speed − fluid tilt^2	.000	−.027	0.000	1.000
Non-ability-based confidence (all ability types) with				
Openness	.317	.286	0.526	0.474
Conscientiousness	.172	.103	0.625	0.374
Extroversion	.317	.051	0.861	0.139
Agreeableness	.069	−.014	1.255	−0.255
Emotional stability	.146	.251	0.368	0.632
Need for cognition	.505	.303	0.625	0.375
Mindset	.091	.010	0.901	0.099
Grit	.265	.161	0.622	0.378
Educational attitudes	.264	−.003	1.011	−0.011
Mastery goal orientation	.231	.232	0.499	0.501
Performance approach	.014	.158	0.081	0.919
Performance avoidance	.006	.185	0.031	0.969
Math − reading tilt	Model did not converge			
Crystallized − fluid tilt	Model did not converge			
Processing speed − crystallized tilt	Model did not converge			
Processing speed − fluid tilt	Model did not converge			
Math − reading tilt^2	−.012	.013	−12.000	13.000
Crystallized − fluid tilt^2	−.029	−.041	0.414	0.586
Processing speed − crystallized tilt^2	−.071	−.040	2.290	−1.290
Processing speed − fluid tilt^2	−.007	−.009	0.437	0.563

Note. The genetic and environmental contribution refers to the amount of the phenotypic correlation attributable to genetic or environmental sources of variance in correlation units (i.e., the sum of the genetic and environmental contribution equals the phenotypic correlation). The proportion of genetic and proportion environment refers to the proportion of the phenotypic correlation attributable to genetic and environmental sources of variance. A refers to genetic factors. E refers to nonshared environmental factors.

experiences. As an illustrative example, consider the bivariate relation between non-ability-based confidence (from fluid intelligence) and openness (see Table 4). The model implied correlation between these variables was $r = .573$. The additive genetic contribution to this correlation was .279 correlation units, and the unique environmental contribution was .294. Thus, 49% (i.e., .279/(.279 + .294)) of the correlation was attributable to genetic factors, and 51% of the correlation was attributable to nonshared environmental factors. We see here that the A pathway accounts for a greater proportion of the correlation than we would expect based on the heritability estimates of non-ability-based confidence. In general, we see a similar pattern across variables, with a few exceptions, mostly among variables with relatively low association with non-ability-based confidence (e.g., agreeableness, educational attitudes, and performance orientations).

Discussion

Non-ability-based confidence, a person's level of confidence that is not consistent with their abilities, is associated with a broad set of personality characteristics and emerges from both genetic factors and unique environmental experiences. Children who strive to think deeper about questions, persevere, want to master concepts, are open, and are more emotionally stable (i.e., are not anxious, depressed, stressed) have higher levels of non-ability-based confidence. That is, as children develop these personality characteristics, they also develop a level of confidence that exceeds the level of their abilities. According to these results, what is captured by a child's confidence is not only their objective ability level but also their willingness to work hard and think deeply as well as their tendency to be open and emotionally stable. These characteristics in concert explain why some children show confidence that exceeds their ability levels while others show confidence that falls short of the potential that their abilities suggest.

In addition to describing the suite of personality variables that correlate with non-ability-based confidence in children, we find that non-ability-based confidence is influenced by both genetic and environmental sources of variance. Across specifications, 9%–28% of the variance in non-ability-based confidence was attributable to genetic sources while the rest was attributable to unique experiences that are not shared among the twins. For context, compared to a set of recently reviewed traits and beliefs ranging from bipolar disorder to musical talent to personality, the magnitude of genetic influences on non-ability-based confidence is much smaller than any other phenotype (Willoughby et al., 2019). This suggests that while genetic factors do play a role in the amount of confidence not calibrated to the ability that a child has, most of the differences in whether a child has high or low levels of non-ability-based confidence were attributable to individual experiences. These experiences could, for example, be experiences with teachers who praise or denigrate or with a cohort of peers that is significantly more or less intelligent than them, possibilities that should be pursued in future research. The environmental sources of variance may also be mediated by other psychological characteristics such as the identified environmental associations with personality. Nonshared environmental influences on personality (Briley & Tucker-Drob, 2014), cognitive ability (Tucker-Drob & Briley, 2014), and school performance (von Stumm & Plomin, 2018) are somewhat stable across time, implying that identifying persistent, person-specific influences on non-ability-based confidence should be feasible.

We also found that the phenotypic associations between non-ability-based confidence and our psychological correlates were attributable to both genetic and environmental sources of variance. We see that a little more than half the correlation was attributable to genetic factors, while the remaining proportion was attributable to nonshared environmental factors. Taken together, the results make headway in understanding where non-ability-based confidence comes from and which children have higher levels.

Limitations

One limitation of this project is that we do not have the power to detect the C component in the ACE model. In each variant of non-ability-based confidence, the 95% confidence interval of the C component in the ACE model included zero. However, rather than assuming that there are no shared environmental influences on non-ability-based confidence, it may be that we do not have a large enough sample size to detect the shared environmental factors. The C component in our analyses (3.4%–8%) is very similar to previous work on non-ability-based confidence which put the C component at 5%–11% with confidence intervals that cross zero (Cesarini et al., 2009). With a larger sample size, we could more precisely estimate the C component, that while small, is of similar magnitude in both studies. We chose to omit the C component for our primary analyses due to convergence concerns, which has the impact of primarily allocating the identified C variance with to the A factor. Thus, our AE estimates of heritability are likely to be upper bound estimates. However, with this consideration in mind, several studies of similar noncognitive skills with much larger twin samples have shown little evidence of shared environment (Malanchini et al., 2017, 2020). Behavior genetic studies often find little evidence of shared environmental influences because environments like home and school that are objectively shared can exert experiential differences for the twins (Plomin & Daniels, 1987). For example, one teaching strategy might be effective for one twin but does not work well for the other twin. Therefore, though the teaching strategy is objectively shared by the twins, it is not experienced similarly by each twin.

The absence of shared environmental variance may also be due to other assumptions of the twin model (Briley et al., 2019). As Purcell (2002) noted, gene–environment interplay could impact parameter estimates when not explicitly modeled. For example, if genetically influenced characteristics are associated with environmental experiences (i.e., gene–environment correlation), then the environmental impact would be subsumed under the A factor. If genetically influenced characteristics lead to differential response to the environment (i.e., Gene × Environment interaction), then either shared or nonshared environmental variation could result. Much larger sample sizes would be necessary to detect such effects.

Another limitation of this data set is the almost exclusive use of self-report measures. With the exception of the ability measures that are standardized cognitive tests, the confidence and psychological correlate items were all self-reported by the child and assessed in the same testing session which may create an issue with common method bias (Podsakoff et al., 2003). When the same method is used to collect all measures in one sitting, we might find higher correlations between variables due to systematic yay-saying or nay-saying on the behalf of the participants rather than a true relation between those variables. Although we cannot rule out common method bias through traditional approaches, the wide range of correlations between non-ability-based confidence and the set of psychological correlates suggests it is unlikely that participants were exclusively yay-saying or nay-saying in their responses. Nevertheless, to rule out common method bias in the future, researchers should use parent or teacher reports to assess the personality of the child while having the child self-report their confidence, an internal motivational state.

Finally, the generalizability of this work is constrained by the secondary data available for these analyses. For example, we can only discuss the genetic and environmental factors of non-ability-based confidence in the context of 7- to 15-year-olds. The pattern may look different in college students or older adults who have learned more and experienced a greater variety of learning environments. In addition, non-ability-based confidence may differ within the same student when it is defined by course grades or SAT scores rather than the standardized cognitive assessments used in this data set. Similarly, whether non-ability-based confidence is domain general or domain specific and how the results might change if non-ability-based confidence was assessed by several math or reading indicators rather than in a more general cognitive ability fashion as done here is an open question. It could be that some people have high levels of non-ability-based confidence when it comes to course grades, or specifically math, while others have high levels of non-ability-based confidence when it comes to general cognitive ability on standardized tests. Such questions are avenues for future research.

Conclusion

Non-ability-based confidence is the amount of confidence that a person has that cannot be explained by their ability level. Our research reveals that non-ability-based confidence is both genetically and environmentally influenced. In addition, we find that children who are open, emotionally stable, willing to work hard, and think deeply about problems are more likely to have high levels of non-ability-based confidence. Given its role in influencing important life outcomes, a promising avenue for research will be to continue exploring the developmental origins of non-ability-based confidence in order to better understand how it operates and why some people are overconfident while others are underconfident.

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Supplemental Material

The supplemental material is available in the online version of the article.

Note

1. We must use caution when interpreting all analyses involving the tilt and tilt^2 variables. There is high collinearity between tilt (which is defined as one ability type minus another ability type) and the latent ability factor that comprises non-ability-based confidence.

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