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Does intelligence predict development of investment traits from mid to late adolescence? Evidence from a 3-year longitudinal study

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Abstract

Introduction: Investment theories have claimed reciprocal relations between intelligence and investment traits (i.e., personality traits related to seeking out, and dealing with, cognitive challenges). However, previous research has primarily addressed the effects of investment traits on intellectual development (environmental enrichment hypothesis) and often focused on either childhood or later adulthood. The present study investigated the effects of intelligence on investment traits (environmental success hypothesis) from mid to late adolescence.

Method: In a 3-year longitudinal survey (2008–2011) covering four measurement occasions, the predictive effects of both fluid and crystallized intelligence on intraindividual change in both the achievement motive (i.e., hope for success and fear of failure) and need for cognition were examined. Overall, 476 adolescents (t_1: $M_{age} = 16.43$, SD = 0.55; 51.3% girls) from Germany participated.

Results: Second-order latent growth models indicated that fluid intelligence predicted a steeper growth in hope for success ($\beta = .40$), but was unrelated to change in the other investment traits. Crystallized intelligence had no effects on the investment traits under study.

Conclusions: The results contribute to the research on the bidirectionality of intelligence and investment traits and add to our understanding of personality development from mid to late adolescence. Specifically, they underline the importance of nurturing hope for success especially in individuals with lower intelligence, but also show that support for the environmental success hypothesis seems to be limited to certain investment traits.

KEYWORDS

achievement motive, Intelligence-personality association, investment theories, late adolescence, need for cognition, personality development

1 | INTRODUCTION

Investment traits have been suggested to play an important role in intellectual development, as they refer to "stable individual differences in the tendency to seek out, engage in, enjoy, and continuously pursue opportunities for effortful cognitive activity" (von Stumm et al., 2011, p. 225). Consequently, longitudinal research in the field has primarily addressed effects of investment traits on intellectual development. However, the relation between intelligence and investment traits might be bidirectional (Ackerman, 1996; Cacioppo & Petty, 1982; Chamorro-Premuzic & Furnham, 2004; Ziegler et al., 2012). Yet, empirical studies on the effect of intelligence on personality development are scarce. Furthermore, the few longitudinal studies primarily focused on adulthood, although adolescence is a key phase in personality development (Soto, 2016;

Soto & Tackett, 2015). In the present study, we analyzed a longitudinal sample of students from mid to late adolescence to examine whether fluid (Gf; basic processing capacities) and crystallized (Gc; cultural knowledge) intelligence (Cattell, 1963; Horn & Cattell, 1966) predict changes in adolescents' need for cognition (NFC) and achievement motives across four-time points within 3 school years.

2 | INVESTMENT TRAITS

Investment traits "determine when, where, and how people invest their time and effort in their intellect" (von Stumm & Ackerman, 2013, p. 841). As such, investment traits might be seen as a specific facet of personal agency, that is, the sense of having control over, and responsibility for, one's own life course and having confidence that obstacles can be overcome (e.g., Côté & Schwartz, 2002; Schwartz et al., 2005). To structure the field of investment traits, Mussel (2013) developed a theoretical framework that distinguishes investment traits according inter alia to the motivational orientation behind them. Two motivational facets can be distinguished: "seek" and "conquer." "Seek" reflects the desire to seek out (or to avoid) cognitive challenges because of affective tendencies linked to those challenges, and thus influences how often individuals will engage in intellectual stimulation. "Conquer" reflects the desire to master (or to withdraw from) cognitive challenges and thus influences how individuals deal with cognitively challenging tasks once they have encountered them.

In the present study, we focused on two investment traits that correspond to these facets in Mussel's (2013) intellect model: achievement motive and NFC. The achievement motive consists of two negatively related components: hope for success (HS) and fear of failure (FF; McClelland et al., 1953). Individuals with high HS have a strong desire for mastering achievement-related situations to experience positive emotions such as pride. They will not only seek for cognitive challenges but will put more effort in a task and show more perseverance especially when faced with obstacles. As the anticipated feeling of pride after a potential success is dominant in individuals with high HS, they do not fear failure or disgrace and thus invest the utmost effort when working on a challenging task (e.g., Atkinson, 1957). Conversely, individuals with high FF have a strong desire to avoid failure in achievement-related situations, because they fear negative consequences of failure (e.g., disgrace and negative emotions such as shame; Heckhausen & Heckhausen, 2018). They will not only avoid cognitive challenges but will show less effort and lower perseverance in achievement-related situations to protect their self (Atkinson, 1957; Brunstein & Maier, 2005; Feather, 1962). For example, they might show self-handicapping strategies such as procrastination or withdrawal, so that they could attribute failure to unfavorable circumstances instead to a lack of ability (Schwinger et al., 2022). As such, the achievement motive can primarily be understood as a "conquer" investment trait.

NFC reflects the "stable individual difference in people's tendency to engage in and enjoy effortful cognitive activity" (Cacioppo et al., 1996, p. 198). For example, an individual with high NFC likes to reflect upon complex ideas and problems. Hence, NFC motivates individuals to actively seek out cognitively demanding tasks and can therefore be primarily seen as a "seek" investment trait (see also Mussel, 2013).

3 | THE RELATION BETWEEN INVESTMENT TRAITS AND INTELLIGENCE

3.1 | Theoretical considerations

In recent decades, many researchers have addressed the question of how investment traits are related to intelligence. Investment theories state that individuals with high scores in investment traits seek out more learning opportunities and show more persistence when working on challenging tasks, which might, in turn, promote intellectual development in the long run (e.g., Ackerman, 1996; Cattell, 1987). However, some investment theories also propose that intelligence might influence personality development. In their Openness-Fluid-Crystallized-Intelligence model, Ziegler et al. (2012) suggested two pathways between intellectual development and development of openness. The *environmental enrichment hypothesis* states that openness promotes the development of Gf (and of Gc through Gf), because individuals with higher openness engage in a greater amount of learning experiences. The *environmental success hypothesis* proposes that individuals with higher Gf can better cope with new situations which might increase their openness. This rationale might apply to investment traits in general. Hypothetically, more intelligent individuals experience more success on cognitively challenging tasks, thus develop more enjoyment of thinking, seek out more cognitive challenges ("seek"), and work harder on cognitively challenging tasks ("conquer") in the future. Other theoretical work also pointed in this direction (Cacioppo et al., 1996; Cattell, 1987; Chamorro-Premuzic & Furnham, 2004; Hill et al., 2013). Regarding Gc, individuals with higher Gc might become curious to learn more and their higher semantic knowledge might enable them to pursue certain activities (e.g., theatre, reading) or educational career pathways that, in turn, train persistence in dealing with cognitive challenges (see Schmiedek et al., 2014).

3.2 | Empirical findings

Numerous studies have identified associations between Gf or Gc, respectively, and investment traits (e.g., Fleischhauer et al., 2010; Hill et al., 2013; von Stumm & Ackerman, 2013). Most studies were, however, cross-sectional, which impedes causal conclusions. Up until now, most longitudinal studies put an emphasis on the environmental enrichment hypothesis (investment traits → intelligence), lending mixed support for it (Bergold & Steinmayr, 2016; Hülür et al., 2018; Staff et al., 2018; Wettstein et al., 2017; Ziegler et al., 2012, 2015).

The environmental success hypothesis (intelligence → investment traits) has been much less examined, and most studies focused on adulthood. Ziegler et al. (2015) followed 516 individuals aged between 70 and 103 over 13 years. Modeling absolute (i.e., intraindividual) change in openness, the authors found no support for the environmental success hypothesis. However, openness barely changed over the study period and only 17% completed the last assessment. Both problems were possibly due to the participants' high ages and might have limited the potential to support the environmental success hypothesis. In a sample of young adults, however, Ziegler et al. (2012, Study 2) could not confirm the environmental success hypothesis.

Von Stumm and Deary (2013) examined cross-lagged reciprocal effects between the investment trait intellect and verbal fluency (an indicator of Gc) at ages 70 and 73. They found that verbal fluency significantly predicted relative change in intellectual curiosity. These results support the environmental success hypothesis, at least with regard to the predictor Gc. Wettstein et al. (2017), using samples in middle and late adulthood, confirmed this finding for both Gc and Gf predicting absolute change in openness and even found that the effects of intelligence on openness were stronger than the reversed effects.

To the best of our knowledge, there is only one study that tested the environmental success hypothesis in a nonadult sample. Bergold and Steinmayr (2016) followed 157 first graders over 9 months and found that Gf tended to predict relative change in HS. Although the effect was practically significant ($\beta = .20$), it missed statistical significance ($p = .097$). As is common in samples of this young age (Spinath, 2004), the students had extremely high HS, which could have attenuated the effect of Gf.

4 | PERSONALITY DEVELOPMENT IN ADOLESCENCE

The few existing research on the environmental success hypothesis has focused on either adulthood or childhood. However, a decisive phase in personality development is adolescence. Adolescence is the phase of transformation from childhood to adulthood, coming with numerous social, psychological, and physical upheavals (e.g., Arnett, 1999; Bogaerts et al., 2021; Erikson, 1968). Meta-analyses on broad personality traits have shown that there is more personality development in adolescence than in adulthood, at least in openness (Bleidorn et al., 2022; Roberts & DelVecchio, 2000; Roberts & Mroczek, 2008; Roberts et al., 2006). Development of openness during adolescence seems to follow a U-shape. Whereas openness was often found to decrease during early adolescence (i.e., from ages 10 to about 15), it was found to increase during late adolescence (i.e., from ages 16 to 18; Allik et al., 2004; McCrae et al., 2002; Pullmann et al., 2006; van den Akker et al., 2014; see Denissen et al., 2013; for meta-analysis). In this crucial phase of personality development, intelligence might not only be an outcome of behaviors guided by investment traits, but also a predictor of investment traits. Older adolescents as compared to children or younger adolescents have already gained more independence from their parents (Arnett, 2000), have a higher sense of personal agency (Côté & Schwartz, 2002; Schwartz et al., 2005), and also have more opportunities to make their own choices for example in school. Therefore, their cognitive abilities might become more decisive for their choices and thus for the development of their investment traits. In addition, by late adolescence intelligence has achieved a high degree of relative and absolute stability and predictive power (McArdle et al., 2002; McCall, 1977; Rost, 2013). Therefore, it has the potential to impact personality development over a time span of several years. Older adolescents' stronger independence and the fact that intelligence is already stable, whereas personality development is especially pronounced makes late adolescence a period predisposed for examining the environmental success hypothesis.

5 | THE PRESENT STUDY

Previous longitudinal studies on the interplay between intelligence and personality primarily focused on the prediction of intellectual development, although the issue of personality development appears by no means less important. This is particularly true for investment traits, given their crucial role for dealing with achievement-related situations and, as a consequence, for cognitive development in the long run (see above). The studies examining the change in investment traits nearly exclusively focused on adulthood, which comes with two disadvantages. First, personality development is less pronounced in adulthood as compared to childhood and adolescence (Roberts & Mroczek, 2008; Roberts et al., 2006). This might have reduced the power to detect effects of intelligence on personality change, which might also explain why findings are hitherto rather inconsistent. Second, a strong focus on adulthood means a neglect of the personality development in younger individuals. Given the high importance of personality development in adolescence, studies should pay particular attention to personality development in this stage of life.

In the present study, we tested the environmental success hypothesis in a sample of 16-year-old adolescents who were followed over 3 school years. We examined growth (and interindividual differences therein) in the achievement motives HE and FF ("conquer") and in NFC ("seek"). Following the adolescents over four waves, we tested whether interindividual differences in growth in these investment traits would be predicted by both Gf and Gc.

Higher levels of both Gf and Gc increase the likelihood of success in achievement-related tasks, which might, in turn, promote the development of both "seek" and "conquer" investment traits. We, therefore, expected that higher Gf and higher Gc would predict stronger growth in HS (Hypothesis 1). As success in achievement-related situations should lower FF, we expected that both Gf and Gc would predict a decrease in FF (Hypothesis 2). As for HS, we expected that higher Gf and higher Gc would predict a steeper growth in NFC (Hypothesis 3).

6 | MATERIAL AND METHODS

6.1 | Participants and procedure

We analyzed data from a longitudinal project focusing on the determinants of academic achievement at the end of secondary school (Steinmayr, 2010). The study was conducted between 2008 and 2011 in five German academic-track schools (Gymnasium). Overall, 476 adolescents ($M_{\text{age}} = 16.43$, SD = 0.55 at t_1; 51.3% girls) were followed over 3 school years. Four measurement occasions were implemented, starting with t_1 at the beginning of 11th grade (2008; $N = 421$). Half a year later, 416 students participated in t_2 (2009) at the beginning of the second 11th-grade term. The last two measurement occasions took place with time intervals of 1 year, that is, at the beginning of the second term in 12th grade (t_3: 2010; $N = 320$) and at the beginning of the second term in 13th grade (t_4: 2011; $N = 289$). The students were tested on regular school days by trained research assistants in groups of about 20 students. Apart from other variables irrelevant for this study, information on gender, age, and socioeconomic status was obtained before the students filled in the questionnaires on the achievement motives and NFC. Last, the students completed the intelligence test at t_1.

6.2 | Measures

Table 1 displays the descriptive statistics, intercorrelations, and reliabilities of all study variables.

6.2.1 | Intelligence

Crystallized (Gc) and fluid intelligence (Gf) were assessed at t_1 with the Intelligence Structure Test 2000-R (Amthauer et al., 2001). The test is based on Cattell's and on Thurstone's intelligence theories and captures both Gc and Gf. The basic module covers the three facets verbal reasoning, numerical reasoning, and figural-spatial reasoning, each of which is measured by three subtests with 20 items each. The composite score indicates general reasoning ability ($\alpha = .89$ in the present sample). The instrument also comprises a general knowledge test. The knowledge test includes 84 items with verbal, numerical, or figural content, covering the domains geography/history, economics, science, mathematics, arts, and daily life. The sum score indicates general knowledge ($\alpha = .76$).

Both the basic module and the knowledge test can be used to determine the factor scores Gc and Gf. Gc is determined by the knowledge test score while accounting for the basic module score (i.e., accounting for the influence of general reasoning ability on the knowledge test score). Conversely, Gf is determined by the basic module score while accounting for the knowledge test score (i.e., accounting for the influence of general knowledge of the basic module score). The test thus provides a pure estimation of both Gc and Gf. The students' mean IQs (reasoning) were 111.5 when compared with the same-aged population and 107.8 when compared with same-aged academic-track students.[1]

[1]Note that we do not report IQs for knowledge or Gf and Gc, because these scales' age norms are coarse-grained (grouping participants aged between 14 and 25 together) and norms for the academic track do not differentiate between age groups whatsoever.

TABLE 1 Means (M), standard deviations (SD), and intercorrelations of the study variables

Variables	*M*	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Gender (0 = boy, 1 = girl)	0.49	0.50	-															
2. Socioeconomic status	56.56	12.75	−0.05	-														
3. Crystallized intelligence	278.89	58.73	−0.37***	0.15**	-													
4. Fluid intelligence	343.97	60.72	−0.31***	0.04	0.21***	-												
5. Hope for success t_1	2.71	0.55	−0.17***	0.08	0.20***	0.15**	*0.78*											
6. Hope for success t_2	2.80	0.58	−0.16**	0.07	0.14**	0.21***	0.52***	*0.82*										
7. Hope for success t_3	2.66	0.61	−0.13*	0.19**	0.15*	0.27***	0.51***	0.56***	*0.84*									
8. Hope for success t_4	2.71	0.63	−0.05	0.12	0.16*	0.29***	0.51***	0.56***	0.59**	*0.85*								
9. Fear of failure t_1	1.74	0.64	0.28***	−0.02	-.28***	−0.29***	−0.28***	−0.31***	−0.30***	−0.25***	*0.85*							
10. Fear of failure t_2	1.82	0.69	0.22***	−0.10	-.26***	−0.27***	−0.33***	−0.33***	−0.44***	−0.38***	0.61***	*0.87*						
11. Fear of failure t_3	1.80	0.75	0.18**	−0.05	-.16**	−0.26***	−0.18**	−0.31***	−0.30***	−0.33***	0.56***	0.57***	*0.91*					
12. Fear of failure t_4	1.78	0.69	0.18**	−0.04	-.23***	−0.17**	−0.21***	−0.16*	−0.23***	−0.32***	0.45***	0.56***	0.60***	*0.89*				
13. Need for cognition t_1	4.50	0.90	−0.07	0.08	.23***	0.18***	0.52***	0.36***	0.43***	0.39***	−0.23***	−0.34***	−0.29***	−0.25***	*0.84*			
14. Need for cognition t_2	4.57	0.96	0.03	0.06	.23***	0.15**	0.41***	0.42***	0.48***	0.47***	−0.20***	−0.37***	−0.31***	−0.29***	0.59***	*0.87*		
15. Need for cognition t_3	4.69	0.98	0.01	0.12	.17**	0.17**	0.34***	0.50***	0.59***	0.51***	−0.26***	−0.46***	−0.43***	−0.34***	0.60***	0.62***	*0.87*	
16. Need for cognition t_4	4.80	1.07	0.04	0.04	0.20**	0.10	0.38***	0.42***	0.51***	0.54***	−0.19**	−0.41***	−0.34***	−0.43***	0.59***	0.67***	0.76***	*0.88*

Note: Figures in italics are Cronach's α values.

*$p < .05$; **$p < .01$; ***$p < .001$.

TABLE 2 Measurement models of hope for success, fear of failure, and need for cognition

Model	χ^2	*df*	*p*	CFI	RMSEA	SRMR
Hope for success t_1	15.29	5	.009	0.976	0.070	0.026
Hope for success t_2	8.73	5	.12	0.993	0.044	0.020
Hope for success t_3	5.45	5	.36	0.999	0.018	0.020
Hope for success t_4	8.76	5	.12	0.990	0.055	0.022
Fear of failure t_1	22.01	5	<.001	0.974	0.090	0.028
Fear of failure t_2	5.32	5	.38	0.999	0.013	0.013
Fear of failure t_3	3.36	5	.65	1.00	0.000	0.010
Fear of failure t_4	8.83	5	.12	0.991	0.056	0.020
Need for cognition t_1	40.65	34	.20	0.993	0.022	0.027
Need for cognition t_2	48.52	34	.20	0.993	0.022	0.029
Need for cognition t_3	64.48	34	.001	0.951	0.058	0.044
Need for cognition t_4	44.62	34	.11	0.986	0.036	0.028

Abbreviations: CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation; SRMR, Standardized Root Mean Square Residual.

6.2.2 | Achievement motive

We applied a short form of the German version (Göttert & Kuhl, 1980) of the Achievement Motive Scale (Gjesme & Nygard, 1970) at all measurement occasions. HS (e.g., "I enjoy working on problems that are difficult for me") and FF (e.g., "Things that are a little difficult worry me") were measured by five items each. The items were answered on a 4-point Likert scale (1 = *not true at all*, 4 = *completely true*). The one-factor measurement models for HS and FF had at least a satisfactory fit (see Table 2).

6.2.3 | NFC

Students completed 10 items (e.g., "Thinking is not my idea of fun") from the German version (Bless et al., 1994) of Cacioppo and Petty's (1982) NFC scale. Each item was answered on a 7-point Likert scale (1 = *totally incorrect*, 7 = *completely accurate*). All items except for two were inverted and recoded so that higher values indicated higher NFC. The assumed one-factor model with correlated errors between the two noninverted items showed a good fit on all measurement occasions (see Table 2).

6.2.4 | Socioeconomic status

Students described their parents' current employment and typical job responsibilities at t_1. We used this information to calculate the parents' Highest International Socioeconomic Index of Occupational Status (Ganzeboom et al., 1992) as an indicator of the family's socioeconomic background. The index has a theoretical range from 16 to 90. In the present sample, it was on average 56.52 (SD = 12.72) and quite diverse with values ranging from 19 to 90.

6.3 | Analyses

6.3.1 | Measurement invariance across time

As a preliminary analysis, we examined the invariance of factor loadings and intercepts over time, which is a prerequisite for longitudinal comparisons of latent means (e.g., Vandenberg & Lance, 2000). We used the Satorra–Bentler corrected χ^2-difference test and the change in both the comparative fit index (ΔCFI) and the root mean square error of approximation (ΔRMSEA) for model comparison. Because of the high sensitivity of the χ^2-difference test to larger sample sizes (Kline, 2015), we put a stronger focus on the other two fit indices. As proposed by Chen (2007), invariance was indicated if ΔCFI < 0.010 and ΔRMSEA < 0.015.

6.3.2 | Latent growth models

We conducted second-order latent growth models to inspect growth in investment traits and to predict interindividual differences in growth. Each investment trait was modeled as a latent variable measured by indicators with invariant factor loadings and intercepts over time. We further allowed correlations between corresponding indicators over time.

We included SES and gender (0 = boy, 1 = girl) as control variables. SES has been shown to impact intellectual development, possibly because of higher-SES parents' stronger support of cognitive activities (e.g., von Stumm & Plomin, 2015). Although strongly understudied as yet, the same might apply to the development of investment traits. Some studies documented gender differences in the development of openness during adolescence (Branje et al., 2007; Klimstra et al., 2009; Soto, 2016; van den Akker et al., 2014). Additionally, as expected for an academic-track sample (e.g., Steinmayr et al., 2015), boys outperformed girls on both Gc ($d = 0.89$, $p < .001$) and Gf ($d = 0.58$, $p < .001$).

The analyses were conducted in Mplus 8.5 (Muthén & Muthén, 2017) and R (R Core Team, 2014). The standard errors were estimated using the robust maximum likelihood estimation procedure. Model fit was assessed with the CFI, the RMSEA, and the Standardized Root Mean Square Residual (SRMR). In addition, we report the χ^2-value along with degrees of freedom (*df*) and *p*-value. The models were considered to have a good fit if CFI ≥ 0.95, RMSEA ≤ 0.06, and the SRMR ≤ 0.08 (Hu & Bentler, 1999). According to less strict recommendations, a satisfactory fit can be indicated by a CFI ≥ 0.90, an RMSEA ≤ 0.08 or ≤0.09, and an SRMR ≤ 0.08 (Browne & Cudeck, 1992; Marsh et al., 2004).

6.3.3 | Missing data

There were two kinds of missing data. First, some of the students missed at least one measurement occasion (see above). The main reason for nonparticipation was illness. However, one school left the study after t_2 due to reasons not related to the investigation. In addition, older students ($rs \geq -0.19$, $ps < 0.001$) and girls ($rs = 0.13$, $ps \leq 0.005$) were more likely to miss a measurement occasion. We accounted for this type of missingness in the final models by inspecting the change in results when dummy-coded school (withdrawal yes/no), age, and gender were included as auxiliary variables. Fifty-eight students missed the intelligence test (only administered at t_1). We decided to exclude these students from the analyses, because (1) convergence problems occurred when the full information maximum likelihood approach for handling missing data was used and (2) there were no significant differences between students with and students without intelligence test scores in NFC ($-0.12 \leq d \leq 0.27$, $ps \geq 0.10$), HS ($-0.03 \leq d \leq 0.04$, $ps \geq 0.82$), and FF ($-0.23 \leq d \leq 0.01$, $ps \geq 0.14$). Second, there were missing data resulting from nonresponse of participating students (t_1: 0.11%, t_2: 0%, t_3: 0.98%, t_4: 0.59%). We used full information maximum likelihood to account for the latter two types of missing data.

7 | RESULTS

7.1 | Measurement invariance

Before the main analyses, we inspected measurement invariance. For each of the investment traits, metric and scalar invariance across time were verified (see Table 3).

7.2 | Growth in investment traits

As a first step, we inspected growth in the investment traits using univariate latent growth models. For HS, the linear model fit the data only trivially worse than a model with unconstrained slope loadings ($\Delta\chi^2 = 12.87$, $p = .002$, ΔCFI = −0.003, ΔRMSEA = 0.002), and we retained the more parsimonious linear model. For FF, the model with free slope loadings did not converge. The NFC model with linear growth did not provide a worse fit to the data than a model with unconstrained slope loadings ($\Delta\chi^2 = 1.56$, $p = .46$, ΔCFI = 0.001, ΔRMSEA < 0.001). All linear growth models indicated at least satisfactory fit (see Table 4, lower part), and growth was linear throughout for boys and girls. Hence, we estimated a linear growth model for all three dependent variables.

Table 4 (upper part) shows the parameter estimates. The average HS score was 2.69 at t_1 and remained unchanged over time. However, the slope variance suggested that there was at least some degree of interindividual differences in growth

TABLE 3 Tests of measurement invariance of hope for success, fear of failure, and need for cognition

Model	χ^2	*df*	S-B $\Delta\chi^2$	Δdf	*p*	CFI	ΔCFI	RMSEA	ΔRMSEA
Hope for success									
Configural invariance	171.71	134				0.985		0.026	
Metric invariance	176.44	146	6.96	12	.86	0.988	0.003	0.022	−0.004
Scalar invariance	192.35	158	15.67	12	.21	0.986	−0.002	0.023	−.0001
Fear of failure									
Configural invariance	155.32	134				0.993		0.020	
Metric invariance	167.92	146	7.55	12	.82	0.993	<0.001	0.019	−0.001
Scalar invariance	196.61	158	28.69	12	.004	0.988	−0.005	0.024	0.005
Need for cognition									
Configural invariance	942.60	670				0.944		0.031	
Metric invariance	967.02	697	30.52	27	.29	0.944	<0.001	0.030	−0.001
Scalar invariance	1,026.24	724	46.90	27	.01	0.938	−0.006	0.032	0.002

Note: CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation; S-B, Satorra-Bentler corrected.

TABLE 4 Latent growth in investment traits

	Hope for success			Fear of failure			Need for cognition		
Parameters	Est.	SE	*p*	Est.	SE	*p*	Est.	SE	*p*
Latent means									
$\mu_{\text{intercept}}$	2.690	0.034	<.001	1.757	0.033	<.001	4.165	0.056	<.001
μ_{slope}	−0.001	0.001	.707	0.001	0.001	.504	0.007	0.001	<.001
Variances									
$\sigma^2_{\text{intercept}}$	0.234	0.029	<.001	0.254	0.033	<.001	0.265	0.060	<.001
σ^2_{slope}	<0.001	<0.001	.063	< 0.001	< 0.001	.002	<0.001	<0.001	.042
Covariances									
$\sigma^2_{\text{intercept, slope}}$	0.001	0.001	.520	-0.002	0.001	.135	0.002	0.001	.090
Model fit									
$\chi^2(df)$	211.55(163), $p = .006$			205.03(163), $p = .014$			1,035.91(729), $p < .001$		
CFI		0.980			0.986			0.937	
RMSEA [90% CI]	0.027 [0.015, 0.036]			0.025 [0.012, 0.035]			0.032 [0.027, 0.036]		
SRMR		0.046			0.043			0.064	

Note: $N = 418$. Unstandardized solution. Slope factor loadings were set at 0 (t_1), 6 (t_2), 18 (t_3), and 30 (t_4).

Abbreviations: CFI, Comparative Fit Index; CI, confidence interval; Est., Estimate; SE, Standard error; RMSEA, Root Mean Square Error of Approximation; SRMR, Standardized Root Mean Square Residual.

($p = .063$). Average base level of FF equaled 1.76. There was no growth on average, but a statistically significant variance in growth. The average NFC score at t_1 equaled 4.17. The slope mean for NFC was significantly positive, indicating that NFC increased over late adolescence. The slope variance showed that there were statistically significant differences in NFC growth.

7.3 | Predicting growth in investment traits from intelligence

To test whether fluid (Gf) and crystallized intelligence (Gc) would positively predict interindividual differences in the growth of the investment traits (Hypotheses 1 to 3), we included Gf, Gc, and the control variables in the models. The results are displayed in Table 5. All models showed at least satisfactory fit (Table 5, lower part).

TABLE 5 Prediction of growth in investment traits

	Hope for success		Fear of failure		Need for cognition	
	β (SE)	p	β (SE)	p	β (SE)	p
DV: Intercept						
IV: Gc	.19 (0.07)	.004	−0.26 (0.05)	<.001	.32 (0.07)	<.001
IV: Gf	.12 (0.06)	.054	−.23 (0.06)	<.001	.20 (0.07)	.002
IV: Gender	−.18 (0.07)	.007	.18 (0.06)	.003	.18 (0.07)	.014
IV: Socioeconomic status	.06 (0.07)	.341	−.01 (0.06)	.914	.07 (0.06)	.293
DV: Slope						
IV: Gc	.15 (0.13)	.264	.09 (0.09)	.331	.11 (0.10)	.261
IV: Gf	.40 (0.16)	.011	−.04 (0.09)	.660	−.08 (0.10)	.424
IV: Gender	.33 (0.16)	.032	−.11 (0.11)	.290	.15 (0.10)	.158
IV: Socioeconomic status	.18 (0.11)	.109	−.02 (0.08)	.814	.02 (0.10)	.812
Model fit						
χ^2 (*df*)	329.28 (238), $p < .001$		322.04 (238), $p < .001$		1316.97 (884), $p < .001$	
CFI	.966		.975		.915	
RMSEA [90% CI]	.030 [.022, 0.038]		.029 [.020, 0.037]		.034 [.030, 0.038]	
SRMR	.048		.045		.065	

Note: $N = 418$.

Abbreviations: CFI, Comparative Fit Index; CI, confidence interval; DV, dependent variable; Gc, crystallized intelligence; Gf, fluid intelligence; IV, independent variable; RMSEA, Root Mean Square Error of Approximation; SE, standard error; SRMR, Standardized Root Mean Square Residual.

Hypothesis 1 had assumed that Gf and Gc would positively predict differences in HS growth. As expected, Gf significantly predicted increase in HS; the effect size was in the medium range ($\beta = .40$, SE = 0.16, $p = .011$). The regression weight of Gc was also in the predicted direction but small and not statistically significant. As for all other predictors, the β weight of Gf did not change notably when the auxiliary variables were included ($\beta = .36$, SE = 0.14, $p = .009$). Thus, Hypothesis 1 was supported for Gf but not for Gc.

We had expected that both Gf and Gc would negatively predict differences in FF growth (Hypothesis 2). Both Gc and Gf predicted lower levels of FF at t_1. However, inconsistent with Hypothesis 2, neither Gc nor Gf were associated with differences in its growth, lending no support for Hypothesis 2. This was also true when the auxiliary variables were included.

Hypothesis 3 had predicted that Gf and Gc would positively predict differences in NFC growth. Both Gc and Gf predicted higher levels of NFC at t_1. However, neither Gc nor Gf predicted absolute change in NFC, lending no support for Hypothesis 3. Considering the auxiliary variables did not change the results. We also conducted a conjoint model including all dependent variables. This model did not reveal notably different results, whether or not the auxiliary variables were included.

8 | DISCUSSION

Many researchers have suggested a reciprocal relation between intelligence and investment traits (e.g., Cacioppo et al., 1996; Cattell, 1987; Chamorro-Premuzic & Furnham, 2004; Ziegler et al., 2012). However, longitudinal studies have neglected both the examination of the effect of intelligence on the development of investment traits and the developmental stage of late adolescence, which is a crucial phase in personality development. To the best of our knowledge, this study is the first analyzing the longitudinal association between Gf and Gc on one hand and investment traits on the other hand in adolescence.

8.1 | Effects of intelligence on growth in investment traits

Maybe the most relevant finding is that Gf predicted growth in HS with a medium effect size ($\beta = .40$). More intelligent adolescents displayed a steeper increase of the will to master achievement-related challenges to experience positive emotions such as pride. This result is in line with the descriptive effect of Gf on relative change in HS found for elementary school children ($\beta = .20$; Bergold & Steinmayr, 2016). The current finding adds to the evidence that intelligence is involved in the development of HS in both childhood and late adolescence. However, the effect size was larger in the present study than in Bergold and Steinmayr (2016). It might be that, as conjectured above, effects of intelligence on investment traits become particularly visible in late adolescence, due to older adolescents' stronger autonomy and sense of personal agency.

Having a higher Gf increases the likelihood of favorable outcomes in achievement-related tasks (Roth et al., 2015), but also of more successful achievement experiences in general (Kuncel et al., 2004). In accordance with the skill development model (Calsyn & Kenny, 1977), more success inside and outside school might lead to more self-confidence, higher ability self-concepts and, subsequently, to increasing levels of HS. Educational achievement might be a key mediator for the found association, a hypothesis that needs to be addressed in future studies and should be extended by further success criteria as possible mediators. Interestingly, Gc did not significantly predict development in HS. According to Cattell's (1963) intelligence model, Gf (as opposed to Gc) is more responsible for success in unknown achievement-related situations, in which prior knowledge is of lower value. Therefore, HS might develop independently from Gc. This might be true especially in adolescence. First, adolescents might be faced with less cognitive challenges that require prior knowledge than are adults. Second, adolescents have not yet gained as much knowledge as have adults and consequently, interindividual differences in their acquired knowledge are not yet that large (e.g., Ackerman, 1996).

Intelligence was negatively associated with FF at each measurement point. However, neither Gc nor Gf predicted the development of FF over time. This result is also in accordance with Bergold and Steinmayr (2016), who found no longitudinal effect of intelligence on FF. One possible explanation could be that less intelligent students might get accustomed to not succeeding in school or elsewhere and subsequently accept failure instead of fearing it (Bergold & Steinmayr, 2016). It is also conceivable that the more intelligent students feel the pressure of increasingly high expectations from their environment leading to an increase of FF, which might in turn cloud the assumed negative effects of intelligence on FF. Furthermore, FF might rather be influenced by other variables, for example, by narrow-sense personality traits such as neuroticism. For instance, Freund and Holling (2011) found that neuroticism predicted current achievement motivation, in particular anxiety, a state-level construct conceptually related to FF. From a theoretical point of view, the different results for HS and FF suggest the necessity to study these two components separately with regard to their potential antecedents and outcomes.

NFC significantly increased over late adolescence, which matches findings for openness (Bleidorn et al., 2022; Roberts et al., 2006). Comparable to achievement motivation, there were small but significant interindividual differences in NFC growth. Both Gc and Gf were associated with base-level NFC. Nevertheless, neither Gc nor Gf predicted growth in NFC over time. This is consistent with the analyses by Ziegler et al. (2012), who did not find any effect of intelligence on the development of openness in young adults. This pattern of findings proposes that the environmental success hypothesis does not hold for NFC either.

In general, Gc did not predict the development of any of the investment traits in this study. The scarce evidence to date concerning the influence of Gc on investment traits stems from middle- or older-aged adult samples (von Stumm & Deary, 2013; Wettstein et al., 2017). The developmental stage could therefore be a relevant factor in this matter. More research is especially needed with a focus on childhood and adolescence. We investigated traits related to the desire to think about complex issues, which corresponds rather with Gf than with Gc (Mussel, 2013). It could be worthwhile to further study the predictive value of intelligence—in particular Gc—with respect to investment traits covering the desire to learn, which would be more closely tied to Gc (Mussel, 2013).

9 | LIMITATIONS AND FUTURE DIRECTIONS

Some limitations need to be considered. First, the current sample consisted exclusively of students from the academic track in Germany ("Gymnasium"). This sample is thus not representative of the same-aged German student population. Students in this type of school tend to be more intelligent (Steinmayr, 2010) and to come from higher-SES families (Nold, 2010). It is possible that variance restrictions in intelligence hindered us from finding more effects on the development of investment traits. Related to this, schooling is not mandatory in Germany at this age. It is plausible that the students in the present sample might differ from the population of adolescents in this age range not only in terms of cognitive abilities but also with respect to their investment traits. Future studies relying on representative adolescent samples are thus needed. Second, because intelligence was only measured at t_1, we could not investigate the development of cognitive ability; hence, we could not examine reciprocal relations. Future research needs to address this by implementing repeated measures of all variables under investigation. Moreover, future studies should integrate potential mediators such as academic achievement to shed light on the developmental processes underlying the effect of intelligence on HS.

10 | CONCLUSION

This study showed that Gf predicts the development of HS in late adolescence. This finding provides support for the environmental success hypothesis at least with regard to HS. This finding implies the necessity to keep HS high especially in less able students, as HS seems to be beneficial for intellectual development. Future studies should investigate academic success as a mediator of the effect found in the present study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study did not receive approval by an ethic committee, because it is a secondary analysis. Institutional approval for this kind of study is not required in Germany. The school administrations had approved the study design and data collection procedure beforehand. The project was conducted in accordance with established ethical standards for psychological research. Anonymity was guaranteed. There was no deception and no intervention possibly causing mental or physical harm. There were no intimate or possibly stigmatizing questions and no special exclusion or inclusion criteria for participation. Participation was voluntary and only allowed if parents had returned a written informed consent.

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