Changes in conscientiousness during adolescence : the role of intelligence

Registered Report

PERSONALITY Science

Personality Science
Volume 6: 1–15

DOI: 10.1177/27000710241309790
journals.sagepub.com/home/ppp
Sage

Changes in conscientiousness during adolescence – the role of intelligence

Teresa Sophie Friedrich[1] and Astrid Schütz[2]

Abstract

Do adolescents become more conscientious to compensate for a lack of intelligence, or does conscientiousness change independent of intelligence? The reasons for personality changes in adolescence have rarely been studied thus far, and in particular, the possible role of intelligence in that process has been neglected. The present study aims to close this research gap. In a large nationwide longitudinal sample of German adolescents (NEPS SC3; $N = 7122$), changes in conscientiousness and the question of whether fluid intelligence influences these changes were investigated. Latent change models indicated that conscientiousness increased in late adolescence, while the trajectories were less clear in early adolescence. Reasoning had a negative effect on changes in conscientiousness in early adolescence, which was more pronounced in boys than in girls.

Keywords

conscientiousness change, fluid intelligence, intelligence compensation hypothesis, adolescence, latent change model, NEPS

Received 11 December 2024; accepted 11 December 2024

Several studies have observed a negative relationship between intelligence and conscientiousness (e.g., Moutafi et al., 2003; Rammstedt et al., 2016), although both constructs are positive predictors of important life outcomes such as academic performance (e.g., Poropat, 2009; Schneider & Preckel, 2017). According to Moutafi et al. (2003, 2004), intelligence may be negatively related to conscientiousness because less intelligent people may become particularly conscientious to compensate for their lack of intelligence. However, other researchers disagree with this assumption and argue that intelligence does not impact changes in conscientiousness (Murray et al., 2014). To our knowledge, no study has tested these two assumptions against each other.

Adolescence is an extremely important phase in personality development (Soto & Tackett, 2015). However, there is little research on the factors that influence changes in conscientiousness in adolescence, and in particular, the role of intelligence in this process has been neglected. The present study aims to close these research gaps with data from a large nationwide panel study (German National Educational Panel Study (NEPS); Blossfeld & Roßbach, 2019).

The intelligence compensation hypothesis

Several empirical investigations have shown that intelligence and conscientiousness are negatively correlated (e.g., Moutafi et al., 2003; Rammstedt et al., 2016). According to the intelligence compensation hypothesis (Moutafi et al., 2003, 2004), this negative relationship may be because conscientiousness is malleable, and changes can occur based on perceived necessities: less intelligent people may compensate for their lack of intelligence by

[1]Department Education, Training, and Employment Over the Life Course, Institute for Employment Research, Nuremberg, Germany
[2]Department of Psychology, University of Bamberg, Bamberg, Germany

Corresponding author:
Teresa Sophie Friedrich, Department Education, Training, and Employment Over the Life Course, Institute for Employment Research, Regensburger Straße 104 D-90478, Nuremberg 90478, Germany.
Email: teresa.friedrich@iab.de

becoming particularly organized, thorough, persistent, and systematic – in other words, particularly conscientious. In contrast, intelligent people may see less necessity to become particularly conscientious, as they can rely on their intelligence to master most (cognitive) tasks.

Fluid intelligence plays a special role in the intelligence compensation hypothesis. Above all, aspects such as reasoning, problem solving, or perceptual speed provide intelligent individuals with an advantage and must be compensated for by conscientiousness if they are not high. However, the empirical results on fluid intelligence are just as inconsistent as those on general intelligence: Some studies have found positive correlations between fluid intelligence and conscientiousness, some have found negative correlations, and some have found nonsignificant correlations (e.g., Ackerman & Heggestad, 1997; Kretzschmar et al., 2018; Moutafi et al., 2006; Soubelet & Salthouse, 2011).

To our knowledge, eight studies to date have approached questions related to the intelligence compensation hypothesis; however, most of these studies were cross-sectional and examined the interaction of intelligence and conscientiousness in predicting academic performance. Five of the eight studies found a significant synergistic interaction term (Bergold & Steinmayr, 2018; Di Domenico & Fournier, 2015; Friedrich & Schütz, 2023; Meyer et al., 2022; Ziegler et al., 2009). The relationship between intelligence and achievement was stronger for conscientious individuals – that is, intelligent individuals benefitted particularly if they were also conscientious. The interactions in the remaining studies were not significant (Beaujean et al., 2011; Brandt & Lechner, 2022; Zhang & Ziegler, 2015).

These results are not in line with the intelligence compensation hypothesis. However, Ziegler et al. (2009) found a significant compensatory interaction term for the facet of achievement striving in low performers: the association between intelligence and achievement was weaker for people high in achievement striving – less intelligent individuals particularly benefitted from being conscientious, and intelligence was a weaker predictor of achievement. Other studies also investigated which conscientiousness facets mainly compensate for intelligence; they found that characteristics such as working hard, being well organized and disciplined especially help one master tasks. Thus, the conscientiousness facets order, self-discipline, and deliberation are particularly relevant for compensating for low intelligence (Moutafi et al., 2006).

In contrast to the intelligence compensation hypothesis, Murray et al. (2014) argued that conscientiousness may be enhanced by intelligence or by a lack of intelligence and that conscientiousness development should therefore be independent of intelligence. Indeed, they argued that intelligence and conscientiousness have only negative relationships in selective samples such as university students or managers. In these cases, selection into the sample is likely to depend on a combination of intelligence and conscientiousness: people with low levels of intelligence can only reach the required performance level if they are particularly conscientious. Conversely, people low in conscientiousness can reach the required performance level only if they are intelligent. This selection bias may lead to a negative relationship between intelligence and conscientiousness in these samples even if there is no such relationship in the population (Murray et al., 2014).

To test their hypothesis, the authors analyzed two cross-sectional samples – an adolescent sample and an adult sample. They simulated compensatory selection by excluding all participants below a certain performance threshold and calculated the correlations between intelligence and conscientiousness in the unselected and selected samples. In all samples (unselected and selected adolescent and adult samples), most correlations were either not significant or positive. Only the correlation with one subscale (achievement striving) in one occupational category (major professionals) in the adult sample became negative in the selective sample (Murray et al., 2014). The results suggested that previously observed negative correlations between intelligence and conscientiousness were not due to selective sampling. Nevertheless, most correlations in that study were not negative. However, analyses of a representative sample of ninth-grade students revealed a negative relationship between intelligence and conscientiousness (Lechner et al., 2017).

In summary, individual theories and empirical studies suggest different relationships between intelligence and conscientiousness. In general, intelligence and conscientiousness can together predict performance in three different ways (following Cohen et al. (2014)). On the one hand, intelligence and conscientiousness can influence performance independently (1- additive effect). An additive effect is suggested in the selection argument (Murray et al., 2014). On the other hand, intelligence and conscientiousness can also influence each other in predicting performance, they can interact. They can either reinforce – high intelligence combined with high conscientiousness results in especially good performance (2- enhancing effect) – or compensate for each other – high scores on one construct can reduce the impact of low scores on the other construct (3- compensatory effect). A compensatory effect is suggested in the intelligence compensation hypothesis.

However, the state of research on the relationship between intelligence and conscientiousness is rather unclear. To determine whether conscientiousness actually compensates for intelligence, it is necessary to examine whether conscientiousness adjusts to intelligence over a longer period. For this purpose, it is necessary to first investigate whether conscientiousness changes in general and whether intelligence is a predictor of this change. Currently, longitudinal analyses examining the joint development of intelligence and conscientiousness in adolescence are lacking.

However, changes in conscientiousness may be especially prominent in adolescence (Soto & Tackett, 2015). To shed further light on the associations over time and understand possible drivers of changes in conscientiousness, we used a large nationwide sample of adolescents and longitudinal data on fluid intelligence and conscientiousness.

Changes in conscientiousness in adolescence

Childhood and adolescence are crucial periods for personality change (Soto & Tackett, 2015); during that period of life, rank order stability is lowest (Roberts & DelVecchio, 2000). Thus, it is of particular interest to investigate changes in conscientiousness and the possible impact of intelligence in this age group.

Studies that have investigated change in conscientiousness in adolescence have identified different trajectories, and it has been difficult to reconcile these findings. In a meta-analysis, Roberts et al. (2006) examined personality changes in ten- to eighteen-year-old adolescents and found no significant changes in conscientiousness in this age group. However, the investigated age span was quite large, and it is possible that opposing trajectories occurred in young and late adolescence, which could have offset each other (Soto et al., 2011). Research seems to support the assumption that conscientiousness decreases in early adolescence and increases in late adolescence (e.g., Denissen et al., 2013; Van den Akker et al., 2014, 2021). To avoid obfuscation of results through such antagonistic processes, we examined students starting in early adolescence and observed changes over time.

In addition, some studies have found different conscientiousness trajectories for boys and girls. On average, girls showed more positive trajectories than boys, i.e., girls became more conscientious (Brandes et al., 2020) or remained stable (Klimstra et al., 2009) in adolescence, whereas boys remained stable or became less conscientious. According to Klimstra et al. (2009), however, the trajectories of change do not differ between boys and girls, but rather the timing of the trajectories differs. The biological and neurological development of girls occurs at an earlier age. Personality maturation is related to this development and occurs earlier in girls. If individuals compensate for intelligence by becoming more conscientious and girls become more conscientious at an earlier age than boys, then it should be the case that girls compensate for intelligence earlier. To account for gender differences in the timing of change in conscientiousness, we analyzed separate conscientiousness trajectories for boys and girls in a multigroup model.

Students and apprentices also differ in their conscientiousness trajectories. For example, Golle et al. (2019) compared personality trajectories between students who participated in academic track schools after grade ten and students who started an apprenticeship. Students in the vocational track became more conscientious than students in the academic track. Students who start working must adopt adult-like roles earlier and take responsibility; thus, these individuals must become more conscientious. Thus, we analyzed a second multigroup model that differentiates between students who continued schooling and students who left school after the ninth or tenth grade.

Most studies thus find a decrease in conscientiousness in early adolescence and increasing conscientiousness trajectories from middle adolescence onward. However, only a few studies to date have examined factors that influence personality changes in adolescence (Israel et al., 2019). A possible explanation for the decrease in conscientiousness in early adolescence and its increase in late adolescence are biological, neurological, and social changes and related challenges in adolescence (Klimstra et al., 2009; Soto et al., 2011). Furthermore, new social roles and associated role expectations require more mature behavior and thus also contribute to a change in personality (Roberts & Wood, 2006). Nevertheless, some of the variance in changes in conscientiousness in adolescence remains unexplained. Intelligence may account for some of the previously unexplained variance. However, intelligence is not the only driver of changes in conscientiousness in adolescence. Therefore, not only less intelligent adolescents do change in conscientiousness, but they might show greater increases than intelligent adolescents.

One of the few studies dealing with predictors of personality change in adolescence investigated the reciprocal relationship between conscientiousness and academic achievement (German and math grades and standardized achievement test results), as well as the influence of parenting styles, in a sample of adolescent students (Israel et al., 2019). The authors analyzed data from the NEPS from students in starting cohort three when they were approximately 13–15 years old. Analyses of cross-lagged panel models revealed a positive relationship between conscientiousness and German and math grades two years later. In addition, math achievement test results were negatively associated with conscientiousness scores two years later.[1] The researchers argued that math achievement increases self-efficacy, which in turn may reduce discipline and diligence. Furthermore, the researchers found correlated changes between conscientiousness and grades in German and math. Students who improved in German and math grades also showed positive changes in conscientiousness. Thus, the results of Israel et al. (2019) are consistent with the intelligence compensation hypothesis; however, they analyzed German and math grades and achievement test results, not intelligence per se or reasoning and perceptual speed test performance, as in the present study.

Unlike in adolescence, there are already studies that have examined the influence of intelligence on change in conscientiousness in old age (see Curtis et al. (2015) for a review). Individuals with higher initial levels or smaller decreases in intelligence decreased less than others in conscientiousness or even increased slightly (e.g., Mõttus et al., 2012; Mueller et al., 2016), which runs contrary to the intelligence compensation hypothesis. However, health has a great influence on changes in cognitive abilities and personality in old age (Wettstein et al., 2017). Therefore, the results of studies involving older participants cannot be generalized to adolescents.

The present study

Adolescence is an important phase in personality development. According to previous studies, conscientiousness declines in early adolescence and increases in late adolescence. However, factors that influence this trajectory have rarely been investigated, and intelligence in particular has been neglected as a factor that may impact such changes. In the present study, we aimed to close this gap and test fluid intelligence as a possible predictor of changes in conscientiousness in adolescence.

Moutafi et al. (2003, 2004) and Murray et al. (2014) provide theoretical considerations on the possible relationship between intelligence and conscientiousness. Both argue that conscientiousness can compensate for intelligence; however, their arguments differ regarding the issue of compensation. The intelligence compensation hypothesis assumes that conscientiousness increases because of a lack of intelligence; in other words, intelligence impacts changes in conscientiousness. In contrast, Murray et al. (2014) did not assume causal effects and attributed the negative relationship between intelligence and conscientiousness in some studies to compensatory selection.

The questions to be answered are as follows: Do less intelligent individuals become more conscientious, or do the conscientiousness trajectories for more and less intelligent individuals not substantially differ? In other words, do our data support the intelligence compensation hypothesis or the selection argument (Murray et al., 2014)? To investigate this research question, longitudinal data are needed. However, to our knowledge, thus far, only cross-sectional studies have investigated the relationship between fluid intelligence and conscientiousness in adolescence.

In the present study, we analyzed longitudinal data from the NEPS (starting cohort 3 (SC3)) to close this gap. The NEPS SC3 data are particularly suitable for investigating whether the intelligence compensation hypothesis or the argument of selection (Murray et al., 2014) holds true, as they include students in all types of schools in Germany and at all ability levels; thus, the NEPS is not a selective sample. In addition, the NEPS has accompanied the participants for more than ten years, from childhood to young adulthood, and provides a wide range of information about this period. Personality and fluid intelligence are each recorded at least twice, which makes it possible to investigate longitudinal changes.

The aim of this study is to clarify the following research questions using latent change and multigroup latent change models: (1) How does conscientiousness change in adolescence? (2) Does fluid intelligence influence conscientiousness trajectories? (3) Are there gender differences in the levels and trajectories of conscientiousness? (4) Are there differences in the levels and trajectories of conscientiousness between students who left school after ninth or tenth grade and students who continued schooling? Regarding the research questions, the following hypotheses were tested:

Hypothesis 1. The conscientiousness of the students decreases between the first and second measurement points (aged 12/13-14/15) and increases between the second and third measurement points (aged 14/15-18/19). Although previous studies have shown differing results, studies with this trajectory pattern have slightly predominated (e.g., Denissen et al., 2013). The conscientiousness scale administered in the present study mainly captures the sub-facet self-discipline. However, the self-discipline and conscientiousness trajectories in adolescence are comparable (Soto et al., 2011). Therefore, we expect that the scale provides results that are comparable to those of studies with broader conscientiousness instruments. Israel et al. (2019) investigated the longitudinal relationship between conscientiousness and academic performance between seventh (age 12/13) and ninth (age 14/15) grades with the NEPS SC3. They found a rank order stability of .77 but did not report conscientiousness trajectories.

Hypothesis 2. In an exploratory fashion, we tested competing hypotheses regarding the intelligence compensation hypothesis. Israel et al. (2019) analyzed the NEPS SC3 and found that standardized mathematics test results in Grade 7 negatively predicted conscientiousness in Grade 9. This suggests that high fluid intelligence also negatively influences changes in conscientiousness. However, the study examined standardized achievement tests instead of intelligence, and other studies came to different conclusions.

H2a: Our data support the intelligence compensation hypothesis – fluid intelligence and conscientiousness change are negatively associated.

H2b: Our data support the selection argument – fluid intelligence and conscientiousness change are not significantly associated.

Hypothesis 3. Consistent with the available research, we expect that girls have more positive trajectories, i.e., a greater increase or less decline in conscientiousness. Specifically, we expect that in girls, the conscientiousness decreases less between the first two measurement points than in boys but increases more between the second and third measurements.

Hypothesis 4. We expect that adolescents who left school after ninth or tenth grade show greater increases in conscientiousness scores between the second and third measurement points than do participants who continue their schooling, which is consistent with previous findings (e.g., Golle et al., 2019). We do not expect any differences between the first and second measurement points, as all participants were in school during this time. There is also a greater focus on cognitive tasks and skills at school than in apprenticeships. Thus, we also expect that the possible impact of fluid intelligence on conscientiousness would be stronger in adolescents who continued school than in those who did not.

Methods

Transparency, openness, and reproducibility

The theory, hypotheses, methods, and R code were preregistered prior to the analyses (https://osf.io/9ekny/?view_only=99e7cbfb08c64527850227563d190344).

This paper used data from the German National Educational Panel Study (NEPS; see Blossfeld & Roßbach, 2019). The NEPS is carried out by the Leibniz Institute for Educational Trajectories (LIfBi, Germany) in cooperation with a nationwide network.

Design and sample

The present study investigated data from the NEPS (NEPS Network, 2021). The NEPS examines education as a lifelong process that includes competence development, educational decisions and returns to education. The NEPS frequently surveys six age cohorts. This provides information from infancy to old age (Blossfeld & Roßbach, 2019).

The present study was based on SC3. SC3 consisted of students who attended fifth grade in the 2010/2011 school year. Since then, students have completed repeated annual surveys. The surveys initially took place in the school context and later in individual personal or telephone interviews. At this time, data for a ten-year period are available. We analyzed data from the 2012/2013, 2014/2015 and 2018/2019 surveys, as personality was assessed in these waves. For the sake of simplicity, we refer to these survey waves as measurement points one, two and three. Students with missing values for all conscientiousness items were excluded from the analyses.

The final sample included 7122 students, of whom 51.7% were boys. In December 2010, when the first intelligence measurement took place, they were, on average, 10.5 years old. Not all participants from the first wave also participated in the survey in 2018/2019. We therefore investigated whether people who participated in both 2010 and 2018/2019 differed in their gender, age, fluid intelligence, and socioeconomic background from those who dropped out before 2018/2019. The results of the chi^2 test and t tests indicated significant differences in gender ($\chi^2(1) = 16.01$, $p < .001$), age ($t(4176.2) = -9.23$, $p < .001$), reasoning ($t(2184.1) = 9.95$, $p < .001$) and perceptual speed ($t(4586) = 3.03$, $p = .0024$) in fifth grade. Boys and older and less intelligent students were more likely to leave the study.

Measurements

Fluid intelligence. The NEPS measures perceptual speed and reasoning, which are both very good indicators of fluid intelligence (Brunner et al., 2014). The picture symbol test (NEPS-BZT) measures perceptual speed and consists of three sets of 31 items each, and the matrices test (NEPS-MAT) measures reasoning and consists of three sets of four items each. The Scientific Use File (SUF) includes sum scores for each perceptual speed subtest and all items of the reasoning test. A maximum of 93 points can be achieved in the picture symbol test, and twelve points can be achieved in the matrices test. The students completed the test in 2010 (fifth grade) and 2015 (ninth grade) (Haberkorn & Pohl, 2013). Brunner et al. (2014) and Lang et al. (2014) provided further information on the tests. Furthermore, reasoning and perceptual speed have practical relevance for investigating the intelligence compensation hypothesis, as they are positively related to grades (e.g., Brandt et al., 2020; Lechner et al., 2017).

Conscientiousness. To date, conscientiousness has been assessed in three waves: 2012/2013, 2014/2015 and 2018/2019. Conscientiousness was measured using a Big Five short scale (BFI-10; Rammstedt & John, 2007) with two items per dimension in 2012/2013 and 2014/2015 and four items in 2018/2019. The two items collected in each wave were 1) "I am thorough when completing my tasks/Ich erledige Aufgaben gründlich" and 2) "I am easy-going and tend to be a bit lazy/Ich bin bequem, neige zur Faulheit". Thus, the items mainly represent self-discipline as a facet of conscientiousness (Rammstedt & Danner, 2017). However, the short version of the conscientiousness scale is strongly correlated (.82) with the long version (Rammstedt & John, 2007). Due to the overlap between the two scales, the short version nevertheless seems suitable for investigating the research question – especially as the conscientiousness facet self-discipline is a likely candidate in the compensation model (Moutafi et al., 2006). The correlations, reliabilities and descriptive statistics are presented in Tables 1 and 2.

Statistical analyses

In the first analysis step, we tested for measurement invariance over time and groups using latent state models. To do so, we specified one latent conscientiousness variable per measurement point, each of which was measured by two indicators. The covariances between the latent variables were estimated freely. To investigate changes in latent means, strong measurement invariance must be obtained. We compared the nested models via chi^2 difference tests and additionally considered goodness-of-fit indices to assess measurement invariance. Measurement invariance is violated if there is a change $\geq -.010$ in TLI, $\geq .015$ in RMSEA and $\geq .030$ (loadings) and .010 (intercepts) in SRMR (Chen, 2007).

We then analyzed a latent change model (Steyer et al., 2000) to examine conscientiousness trajectories in adolescence in general. Latent change models can be applied to investigate similar issues as latent growth curve models – to measure individual differences in intra-individual change over time without measurement errors. The main difference between the models is that latent change models do not specify the form of change (for example, linear or quadratic change) as latent growth curve models do. Therefore, they are less restrictive. Furthermore, latent change models measure the change between two explicit measurement points (for example, between waves 1-2 or 2-3), whereas latent growth curve models examine the change over an entire period (Steyer et al., 2000). In addition, certain parameters need to be fixed so that latent growth curve models with only three measurements can be identified. Because of these advantages, we selected latent change models.

In the latent change model, the latent difference between two variables is added to the model as an additional latent variable. This latent change variable is modeled by reformulating the latent variables in the structural equation model (SEM). The change variables can be both exogenous and endogenous variables in the model (Steyer et al., 1997, 2000). Intelligence can therefore predict the change variables in the model and thus the change in conscientiousness.

In the next step, we included a latent perceptual speed and reasoning variable as predictors of the change variables to investigate whether intelligence influences conscientiousness trajectories. Instead of specifying a higher-order factor, "fluid intelligence", we calculated separate models for perceptual speed and reasoning. On the one hand, the NEPS unit responsible for competence testing recommends this approach from a psychometric point of view because the underlying data and modeling differ between the two tests. Furthermore, that procedure seems reasonable for reasons of comparability: other papers with NEPS data also analyze reasoning and perceptual speed separately or only analyze reasoning (e.g., Brandt et al., 2020; Lechner et al., 2017). Since both reasoning and perceptual speed are indicators of fluid intelligence, we do not expect different results for the two scales.

Moreover, longer education is related to increases in intelligence. In other words, intelligence changes over a school career (Ritchie & Tucker-Drob, 2018). To address this issue, we used both fifth- and ninth-grade intelligence measures in the analyses. We predicted change in conscientiousness between 12/13 and 14/15 years of age with fifth-grade intelligence and change in conscientiousness between 14/15 and 18/19 years of age with ninth-grade intelligence. Figure 1 shows an example SEM.

Table 1. Descriptives.

	n	Mean	sd	Min	Max	α
Conscientiousness w1	6716	3.22	0.86	1	5	0.53
Conscientiousness w2	5599	3.05	0.84	1	5	0.5
Conscientiousness w3	3846	3.56	0.79	1	5	0.53
Reasoning grade 5	4203	7.15	2.5	0	12	0.65
Reasoning grade 9	4405	9.29	2.18	0	12	0.65
Perceptual speed grade 5	4588	44.45	13.21	0	93	0.79
Perceptual speed grade 9	4571	63.31	13.24	0	93	0.79

Note. Own calculations based on NEPS SC3: 12.1.0.

Table 2. Correlations.

	1	2	3	4	5	6	7	8	9	10
1 Conscientiousness w1	**1**									
2 Conscientiousness w2	**0.51**	**1**								
3 Conscientiousness w3	**0.38**	**0.47**	**1**							
4 Reasoning grade 5	**−0.03**	**−0.11**	**−0.05**	**1**						
5 Reasoning grade 9	0.00	**−0.06**	**−0.07**	**0.5**	**1**					
6 Perceptual Speed grade 5	0.00	−0.02	0.01	**0.12**	**0.09**	**1**				
7 Perceptual Speed grade 9	**0.07**	**0.04**	**0.04**	**0.14**	**0.20**	**0.31**	**1**			
8 Boy	**−0.18**	**−0.16**	**−0.21**	**0.05**	−0.01	**−0.10**	**−0.16**	**1**		
9 Age	−0.01	**0.04**	**0.04**	**−0.13**	**−0.17**	**−0.03**	**−0.08**	**0.08**	**1**	
10 Hisei	0.03	**−0.03**	−0.01	**0.19**	**0.19**	−0.01	**0.06**	**0.03**	**−0.18**	**1**
11 Continuing school	**0.08**	0.00	**−0.03**	**0.30**	**0.32**	**0.08**	**0.18**	**−0.08**	**−0.24**	**0.27**

Note. Own calculations based on NEPS SC3: 12.1.0; numbers in bold are significant with $p < .05$.

Next, we calculated a multigroup model for gender to investigate whether girls and boys differ in their conscientiousness trajectories. We then calculated another multigroup model separately for people who left school after Grade nine/ten and people who stayed in school. More precisely, students who left school between 2015 and 2017 are in one group, and students who left school after 2017 are in the other group. Students who dropped out of the study were assigned a missing value due to incomplete information on their school career. Since especially high-achieving students remain in school after the ninth/tenth grade, it is possible that the groups differ in intelligence and conscientiousness. Therefore, in the SEM, we additionally calculated whether the groups differed in intelligence and baseline conscientiousness. Similarly, we examined the differences between boys and girls.

As we found significant differences in gender and age between individuals who dropped out of the study and individuals who participated in the current wave, we ran additional models in which we controlled for these variables to test the robustness of the results.

The analyses were performed in the statistical software R (R Core Team, 2022). As students are nested in classes, we corrected the standard errors with the "cluster" argument of the SEM function in lavaan (Rosseel, 2012). The full information maximum likelihood (FIML) approach was used in all analyses to address missing values.

Furthermore, all the statistical tests were performed with a significance level of $\alpha = 5\%$. Since the chi^2 test statistic depends on sample size (Hu & Bentler, 1995), the model fit was assessed by alternative fit indices in this paper: the root-mean-square error of approximation (RMSEA) should be smaller than .06 for an acceptable model fit, the standardized root-mean-square residual (SRMR) should be smaller than .08, and the comparative fit index (CFI) and the Tucker–Lewis Index (TLI) should both be above .95 (Hu & Bentler, 1999).

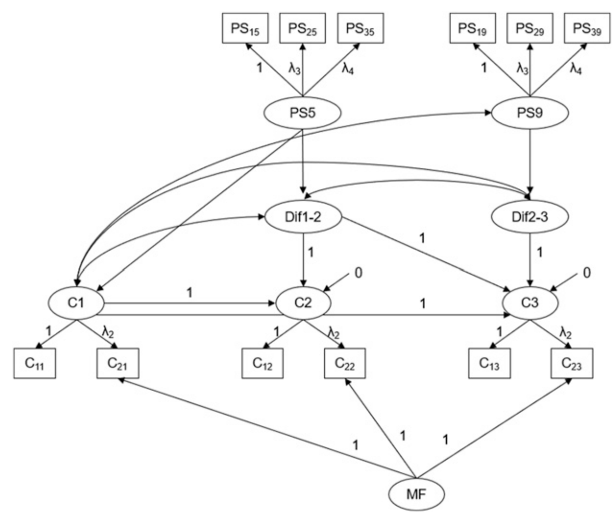

Figure 1. Latent change model with perceptual speed. Representation of the implemented latent change model with perceptual speed predicting conscientiousness change based on Geiser (2010). C1 = conscientiousness time 1, Dif1-2 = latent change variable time 1-2, MF = method factor, PS5 = perceptual speed Grade 5.

As conscientiousness was measured with the same items at each measurement point, the residuals are not random and uncorrelated. Thus, a method factor dealt with indicator-specific effects in all SEMs (Eid, 2000).

Results

First, we assessed measurement invariance over time and groups for conscientiousness, perceptual speed and reasoning. For some models, measurement invariance was not present, and we implemented partial measurement invariance. Table A1 reports further information and the results of the measurement invariance tests.

Next, we estimated a latent change model to investigate conscientiousness change in general. The model fit the data well (CFI = 0.997, TLI = 0.991, RMSEA = 0.026, SRMR = 0.010). Conscientiousness did not change significantly between 12/13 and 14/15 years of age but increased between 14/15 and 18/19 years of age (Δ = 0.625***). Baseline conscientiousness and the two change variables showed significant variance, indicating that students differed in conscientiousness at age 12/13 and in their individual changes in conscientiousness. Furthermore, we found significant covariances between baseline conscientiousness and the two change variables: higher baseline conscientiousness was associated with less increase over time.

To reveal the effect of fluid intelligence on conscientiousness development, we next included perceptual speed and reasoning in the models. The model with perceptual speed showed a good fit (CFI = 0.989, TLI = 0.985, RMSEA = 0.028, SRMR = 0.026), while the fit for reasoning was not good (CFI = 0.916, TLI = 0.912, RMSEA = 0.026, SRMR = 0.031). Therefore, we deviated from our preregistered analyses and built three parcels with 4 indicators each. This corresponds to the three sets of the reasoning test and parallels the perceptual speed analyses. The reasoning model with three parcels fit the data well (CFI = 0.981, TLI = 0.974, RMSEA = 0.030, SRMR = 0.026). We additionally ran the preregistered reasoning model with 12 indicators as a robustness check and found no meaningful differences between this model and the model with parcels.

Perceptual speed had no significant effect on conscientiousness development, while reasoning negatively predicted changes in conscientiousness between 12/13 and 14/15 years of age (b = −0.121***). Students with higher reasoning levels in Grade 5 increased less in conscientiousness between the ages of 12/13 and 14/15. Interestingly, the change in conscientiousness between 12/13 and 14/15 years of age was no longer non-significant in these models; instead, conscientiousness increased during this period.

To identify differences between boys and girls and between students who had left school after ninth/tenth grade and those who had continued schooling, we next analyzed multigroup models. For boys, conscientiousness increased over the entire period from 12/13 to 18/19 years of age. Both perceptual speed and reasoning were negatively associated with the increase in conscientiousness that occurred between 12/13 and 14/15 years of age. For girls, conscientiousness trajectories between 12/13 and 14/15 years of age were not clear; however, they increased between 14/15 and 18/19 years of age. For girls, only reasoning was significantly associated with changes in conscientiousness. Compared with boys, girls showed greater baseline conscientiousness and greater perceptual speed, whereas boys showed greater reasoning in fifth grade and greater changes in conscientiousness between 12/13 and 14/15 years of age.

For students who had left school after ninth/tenth grade as well as for students who had continued schooling, neither perceptual speed nor reasoning had any significant effects on conscientiousness change. However, reasoning negatively predicted change in conscientiousness between 12/13 and 14/15 years of age at the 10% level for students who stayed in school. In both groups, conscientiousness changed significantly between 14/15 and 18/19 only. Students who had left school and those who continued schooling differed in their reasoning and perceptual speed abilities.

To test the robustness of the results, we additionally calculated latent change models using a parametrization introduced by Steyer et al. (2000). These models showed exactly the same results as the parametrization used in the present study. Furthermore, we ran additional models in which we controlled for gender and age, as people who dropped out of the study differed in these two variables. In the models with control variables, we found more or less the same results as in the models without them.

Discussion

The present study aimed to answer four research questions. First, how does conscientiousness change in adolescence? The change in conscientiousness in early adolescence (aged 12/13 to 14/15) was not uniform. In late adolescence (aged 14/15 to 18/19), conscientiousness clearly increased. This finding is mostly in line with previous research and our hypothesis. New social roles in late adolescence and young adulthood result in normative increases in conscientiousness and other mature personality traits.

Notably, in the present study, conscientiousness increased significantly in early adolescence once intelligence was included in the models. Intelligence had a negative effect on conscientiousness change at this age (even if this effect was not always significant), more intelligent students experienced smaller increases. This could mean that in previous models without intelligence, conscientiousness change was underestimated.

This effect of intelligence was addressed in our second research question. Nevertheless, the results are not uniform but differ among subgroups and depend on the intelligence indicator. However, it is clear that the increase in conscientiousness in *late* adolescence was unrelated to intelligence. It appears that other reasons, such as new social roles, account for the trajectory. However, in *early* adolescence, there is evidence of compensation. Across most groups, reasoning was related to changes in conscientiousness in early adolescence: The conscientiousness of more intelligent students increased less strongly. This result is in line with Israel et al. (2019), who found a negative relationship between conscientiousness and math achievement test scores in early adolescence. However, reasoning had a greater impact on changes in conscientiousness than did perceptual speed, possibly because it is a more general factor that could have a broader impact on success in school and work.

The impact of intelligence on changes in conscientiousness differed between boys and girls, which was the subject of the third research question. For boys with higher perceptual speed and reasoning, we observed smaller increases in conscientiousness in early adolescence. For girls, reasoning and, particularly, perceptual speed were less relevant; only reasoning influenced conscientiousness change – possibly due to gender roles and related differences in conscientiousness – and girls had higher baseline conscientiousness.

The fourth research question addressed those who had left school after ninth/tenth grade versus those who had continued schooling. Neither group experienced a significant change in conscientiousness in early adolescence. Nevertheless, overall, the direction of the effect of reasoning on change in conscientiousness in early adolescence was negative in both school subgroups.

Limitations

The present study has several limitations regarding the measurement of conscientiousness: conscientiousness was measured with only two of the original nine items of the BFI. Thus, the items do not reflect the full breadth of conscientiousness but rather focus mainly on self-discipline. However, the short scale correlates very highly with the long version (.82; Rammstedt & John, 2007). Obviously, the reliability of the short scale is reduced. Nevertheless, "given its brevity, the BFI-10 possesses acceptable psychometric properties"; the test-retest stability is .77, and the correlation between self- and peer ratings is .38 (Rammstedt & John, 2007, p. 210).

Furthermore, in previous studies, the conscientiousness facet 'striving for achievement' has proven to be relevant in compensating for lack of intelligence (Ziegler et al., 2009). Future studies should thus capture conscientiousness broader than in the present study and consider this aspect.

When specifying partial measurement invariance, it became clear that depending on the implementation of partial measurement invariance, the conscientiousness trajectories differed. We decided in favor of the current implementation, as the model showed a very good fit and the conscientiousness trajectories mostly reflect the current state of research.

In addition to measurement issues, we investigated multigroup models with students who left school after ninth/tenth grade and students who remained at school. In particular, high-achieving students continue schooling. The groups differed in terms of intelligence and conscientiousness. Restricted variance in the multigroup models could affect the results. Nevertheless, we would consider it more problematic for the present research to lump all participants together, as previous studies found different conscientiousness trajectories for students and apprentices (e.g., Golle et al., 2019).

Conclusion

Does fluid intelligence influence conscientiousness trajectories, or does conscientiousness change independent of intelligence? In students with lower reasoning ability, conscientiousness increased more strongly in early adolescence than it did in students with higher reasoning ability. This was also true for perceptual speed – in boys only, however. This result supports the hypothesis that intelligence influences conscientiousness trajectories: more intelligent students are likely less dependent on conscientiousness (compensation hypothesis). However, the effect was not found when students who had left school after ninth or tenth grade were analyzed separately.

The phenomenon of intelligence compensation has implications for assessment practices. As both intelligence and conscientiousness can predict achievement, both constructs should be administered and considered to adequately predict performance. Furthermore, both constructs should be accounted for when selecting applicants for universities, apprenticeships, or jobs, as conscientious individuals can compensate for a possible lack of intelligence and perform well.

Key insights

- Conscientiousness increased in late adolescence.
- Reasoning was negatively associated with conscientiousness trajectories.
- This association was more pronounced in boys than in girls.

Relevance statement

Using large nationwide panel data, the paper examines whether intelligence influences changes in conscientiousness and thus provides new insights into factors of personality changes in adolescence.

Authors note

Not applicable.

Acknowledgements

Not applicable.

Author contributions

Teresa Sophie Friedrich: Conceptualization; Formal analysis; Investigation; Methodology; Project administration; Software; Validation; Visualization; Writing - original draft, and Writing - review & editing.
Astrid Schütz: Conceptualization; Supervision; Writing - review & editing.

Declaration of conflicting interests

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

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Not applicable.

Data accessibility statement

Researchers can request the data via the research data center (FDZ) of the Leibniz-Institut für Bildungsverläufe (LIfBi; https://www.neps-data.de/Data-Center/Data-and-Documentation/Start-Cohort-Grade-5/Data-and-Citation).

Supplemental material

Supplemental material for this article is available online. Depending on the article type, these usually include a Transparency Checklist, a Transparent Peer Review File, and optional materials from the authors.

Note

1. Grades were recoded such that high values indicated good performance.

References

Ackerman, P. L., & Heggestad, E. D. (1997). Intelligence, personality, and interests: Evidence for overlapping traits. *Psychological Bulletin*, *121*(2), 219–245. https://doi.org/10.1037/0033-2909.121.2.219

Beaujean, A. A., Firmin, M. W., Attai, S., Johnson, C. B., Firmin, R. L., & Mena, K. E. (2011). Using personality and cognitive ability to predict academic achievement in a young adult sample. *Personality and Individual Differences*, *51*(6), 709–714. https://doi.org/10.1016/j.paid.2011.06.023

Bergold, S., & Steinmayr, R. (2018). Personality and intelligence interact in the prediction of academic achievement. *Journal of Intelligence*, *6*(2), 27. https://doi.org/10.3390/jintelligence6020027

Blossfeld, H.-P., & Roßbach, H.-G. (Eds.), (2019). *Education as a lifelong process: The German National Educational Panel Study (NEPS)* (Vol. 3). Springer. https://doi.org/10.1007/978-3-658-23162-0

Brandes, C. M., Kushner, S. C., Herzhoff, K., & Tackett, J. L. (2020). Facet-level personality development in the transition to adolescence: Maturity, disruption, and gender differences. *Journal of Personality and Social Psychology*, *121*(5), 1095–1111. https://doi.org/10.1037/pspp0000367

Brandt, N. D., & Lechner, C. M. (2022). Fluid intelligence and competence development in secondary schooling: No evidence for a moderating role of conscientiousness. *Journal of Intelligence*, *10*(2), 1–24. https://doi.org/10.3390/jintelligence10020027

Brandt, N. D., Lechner, C. M., Tetzner, J., & Rammstedt, B. (2020). Personality, cognitive ability, and academic performance: Differential associations across school subjects and school tracks. *Journal of Personality*, *88*(2), 249–265. https://doi.org/10.1111/jopy.12482

Brunner, M., Lang, F. R., & Lüdtke, O. (2014). *Erfassung der fluiden kognitiven Leistungsfähigkeit über die Lebensspanne im Rahmen der National Educational Panel Study: Expertise [Assessment of fluid cognitive performance across the lifespan in the National Educational Panel Study: Expertise]*. Leibniz-Institut für Bildungsverläufe, Nationales Bildungspanel.

Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2014). *Applied multiple regression/correlation analysis for the behavioural sciences*. Psychology Press. https://doi.org/10.4324/9781410606266

Curtis, R. G., Windsor, T. D., & Soubelet, A. (2015). The relationship between Big-5 personality traits and cognitive ability in older adults – a review. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *22*(1), 42–71. https://doi.org/10.1080/13825585.2014.888392

Denissen, J. J. A., van Aken, M. A. G., Penke, L., & Wood, D. (2013). Self-regulation underlies temperament and personality: An integrative developmental framework. *Child Development Perspectives*, *7*(4), 255–260. https://doi.org/10.1111/cdep.12050

Di Domenico, S. I., & Fournier, M. A. (2015). Able, ready, and willing: Examining the additive and interactive effects of intelligence, conscientiousness, and autonomous motivation on undergraduate academic performance. *Learning and Individual Differences*, *40*, 156–162. https://doi.org/10.1016/j.lindif.2015.03.016

Eid, M. (2000). A multitrait-multimethod model with minimal assumptions. *Psychometrika*, *65*(2), 241–261. https://doi.org/10.1007/BF02294377

Friedrich, T. S., & Schütz, A. (2023). Predicting school grades: Can conscientiousness compensate for intelligence? *Journal of Intelligence*, *11*(7), 146. https://doi.org/10.3390/jintelligence11070146

Geiser, C. (2010). *Datenanalyse mit Mplus: Eine anwendungsorientierte Einführung [data analysis with Mplus: an application-oriented introduction]*. VS Verlag für Sozialwissenschaften.

Golle, J., Rose, N., Göllner, R., Spengler, M., Stoll, G., Hübner, N., Rieger, S., Trautwein, U., Lüdtke, O., Roberts, B. W., & Nagengast, B. (2019). School or work? The choice may change your personality. *Psychological Science*, *30*(1), 32–42. https://doi.org/10.1177/0956797618806298

Haberkorn, K., & Pohl, S. (2013). *Cognitive basic skills – data in the scientific use file*. University of Bamberg, National Educational Panel Study.

Hu, L.-T., & Bentler, P. M. (1995). Evaluating model fit. In *Structural equation modeling: Concepts, issues, and applications* (pp. 76–99). Sage.

Hu, L.-T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Israel, A., Lüdtke, O., & Wagner, J. (2019). The longitudinal association between personality and achievement in adolescence: Differential effects across all big five traits and four achievement indicators. *Learning and Individual Differences*, *72*, 80–91. https://doi.org/10.1016/j.lindif.2019.03.001

Klimstra, T. A., Hale, W. W., Raaijmakers, Q. A. W., Branje, S. J. T., & Meeus, W. H. J. (2009). Maturation of personality in adolescence. *Journal of Personality and Social Psychology*, *96*(4), 898–912. https://doi.org/10.1037/a0014746

Kretzschmar, A., Spengler, M., Schubert, A.-L., Steinmayr, R., & Ziegler, M. (2018). The relation of personality and intelligence—what can the Brunswik symmetry principle tell us? *Journal of Intelligence*, *6*(3), 30. https://doi.org/10.3390/jintelligence6030030

Lang, F. R., Kamin, S., Rohr, M., Stünkel, C., & Williger, B. (2014). *Erfassung der fluiden kognitiven Leistungsfähigkeit über die Lebensspanne im Rahmen des Nationalen Bildungspanels: Abschlussbericht zu einer NEPS-Ergänzungsstudie [Assessment of fluid cognitive performance across the lifespan within the framework of the National Educational Panel Study: Final report on an NEPS supplementary study]*. Leibniz-Institut für Bildungsverläufe, Nationales Bildungspanel.

Lechner, C., Danner, D., & Rammstedt, B. (2017). How is personality related to intelligence and achievement? A replication and extension of Borghans et al. and Salkever. *Personality and Individual Differences*, *111*, 86–91. https://doi.org/10.1016/j.paid.2017.01.040

Meyer, J., Lüdtke, O., Schmidt, F. T. C., Fleckenstein, J., Trautwein, U., & Köller, O. (2022). Conscientiousness and cognitive ability as predictors of academic achievement: Evidence of synergistic effects from integrative data analysis. *European Journal of Personality*, *38*(1), 36–52. https://doi.org/10.1177/08902070221127065

Mõttus, R., Johnson, W., Starr, J. M., & Deary, I. J. (2012). Correlates of personality trait levels and their changes in very old age: The Lothian Birth Cohort 1921. *Journal of Research in Personality*, *46*(3), 271–278. https://doi.org/10.1016/j.jrp.2012.02.004

Moutafi, J., Furnham, A., & Crump, J. (2003). Demographic and personality predictors of intelligence: A study using the neo personality inventory and the Myers–Briggs type indicator. *European Journal of Personality*, *17*(1), 79–94. https://doi.org/10.1002/per.471

Moutafi, J., Furnham, A., & Crump, J. (2006). What facets of openness and conscientiousness predict fluid intelligence score? *Learning and Individual Differences*, *16*(1), 31–42. https://doi.org/10.1016/j.lindif.2005.06.003

Moutafi, J., Furnham, A., & Paltiel, L. (2004). Why is conscientiousness negatively correlated with intelligence? *Personality and Individual Differences*, *37*(5), 1013–1022. https://doi.org/10.1016/j.paid.2003.11.010

Mueller, S., Wagner, J., Drewelies, J., Duezel, S., Eibich, P., Specht, J., Demuth, I., Steinhagen-Thiessen, E., Wagner, G. G., & Gerstorf, D. (2016). Personality development in old age relates to physical health and cognitive performance: Evidence from the Berlin Aging Study II. *Journal of Research in Personality*, *65*, 94–108. https://doi.org/10.1016/j.jrp.2016.08.007

Murray, A. L., Johnson, W., McGue, M., & Iacono, W. G. (2014). How are conscientiousness and cognitive ability related to one another? A re-examination of the intelligence compensation hypothesis. *Personality and Individual Differences*, *70*, 17–22. https://doi.org/10.1016/j.paid.2014.06.014

NEPS Network. (2021). *National educational panel study, scientific use file of starting cohort grade 5*. Leibniz Institute for Educational Trajectories (LIfBi). https://doi.org/10.5157/NEPS:SC3:11.0.1

Poropat, A. E. (2009). A meta-analysis of the five-factor model of personality and academic performance. *Psychological Bulletin*, *135*(2), 322–338. https://doi.org/10.1037/a0014996

Rammstedt, B., & Danner, D. (2017). Die Facettenstruktur des Big Five Inventory (BFI): Validierung für die deutsche Adaptation des BFI [the facet structure of the Big Five Inventory (BFI): Validation for the German adaptation of the BFI]. *Diagnostica*, *63*(1), 70–84. https://doi.org/10.1026/0012-1924/a000161

Rammstedt, B., Danner, D., & Martin, S. (2016). The association between personality and cognitive ability: Going beyond simple effects. *Journal of Research in Personality*, *62*, 39–44. https://doi.org/10.1016/j.jrp.2016.03.005

Rammstedt, B., & John, O. P. (2007). Measuring personality in one minute or less: A 10-item short version of the Big five inventory in English and German. *Journal of Research in Personality*, *41*(1), 203–212. https://doi.org/10.1016/j.jrp.2006.02.001

R Core Team. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Ritchie, S. J., & Tucker-Drob, E. M. (2018). How much does education improve intelligence? A meta-analysis. *Psychological Science*, *29*(8), 1358–1369. https://doi.org/10.1177/0956797618774253

Roberts, B. W., & DelVecchio, W. F. (2000). The rank-order consistency of personality traits from childhood to old age: A quantitative review of longitudinal studies. *Psychological Bulletin*, *126*(1), 3–25. https://doi.org/10.1037/0033-2909.126.1.3

Roberts, B. W., Walton, K. E., & Viechtbauer, W. (2006). Patterns of mean-level change in personality traits across the life course: A meta-analysis of longitudinal studies. *Psychological Bulletin*, *132*(1), 1–25. https://doi.org/10.1037/0033-2909.132.1.1

Roberts, B. W., & Wood, D. (2006). Personality development in the context of the neo-socioanalytic model of personality. In *Handbook of personality development* (pp. 11–39). Erlbaum.

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(2), 1–36. https://doi.org/10.18637/jss.v048.i02

Schneider, M., & Preckel, F. (2017). Variables associated with achievement in higher education: A systematic review of meta-analyses. *Psychological Bulletin*, *143*(6), 565–600. https://doi.org/10.1037/bul0000098

Soto, C. J., John, O. P., Gosling, S. D., & Potter, J. (2011). Age differences in personality traits from 10 to 65: Big Five domains and facets in a large cross-sectional sample. *Journal of Personality and Social Psychology*, *100*(2), 330–348. https://doi.org/10.1037/a0021717

Soto, C. J., & Tackett, J. L. (2015). Personality traits in childhood and adolescence: Structure, development, and outcomes. *Current Directions in Psychological Science*, *24*(5), 358–362. https://doi.org/10.1177/0963721415589345

Soubelet, A., & Salthouse, T. A. (2011). Personality–cognition relations across adulthood. *Developmental Psychology*, *47*(2), 303–310. https://doi.org/10.1037/a0021816

Steyer, R., Eid, M., & Schwenkmezger, P. (1997). Modeling true intraindividual change: True change as a latent variable. *MPR Online*, *2*(1), 21–33.

Steyer, R., Partchev, I., & Shanahan, M. J. (2000). Modeling true intraindividual change in structural equation models: The case of poverty and children's psychosocial adjustment. In T. D. Little, K. U. Schnabel, & J. Baumert (Eds.), *Modeling longitudinal and multilevel data. Practical issues, applied approaches, and specific examples* (pp. 109–126). Erlbaum.

Van den Akker, A. L., Briley, D. A., Grotzinger, A. D., Tackett, J. L., Tucker-Drob, E. M., & Harden, K. P. (2021). Adolescent Big Five personality and pubertal development: Pubertal hormone concentrations and self-reported pubertal status. *Developmental Psychology*, *57*(1), 60–72. https://doi.org/10.1037/dev0001135

Van den Akker, A. L., Deković, M., Asscher, J., & Prinzie, P. (2014). Mean-level personality development across childhood and adolescence: A temporary defiance of the maturity principle and bidirectional associations with parenting. *Journal of Personality and Social Psychology*, *107*(4), 736–750. https://doi.org/10.1037/a0037248

Wettstein, M., Tauber, B., Kuźma, E., & Wahl, H.-W. (2017). The interplay between personality and cognitive ability across 12 years in middle and late adulthood: Evidence for reciprocal associations. *Psychology and Aging*, *32*(3), 259–277. https://doi.org/10.1037/pag0000166

Zhang, J., & Ziegler, M. (2015). Interaction effects between openness and fluid intelligence predicting scholastic performance. *Journal of Intelligence*, *3*(3), 91–110. https://doi.org/10.3390/jintelligence3030091

Ziegler, M., Knogler, M., & Bühner, M. (2009). Conscientiousness, achievement striving, and intelligence as performance predictors in a sample of German psychology students: Always a linear relationship? *Learning and Individual Differences*, *19*(2), 288–292. https://doi.org/10.1016/j.lindif.2009.02.001

Appendix

Table A1. Measurement Invariance Analyses.

Model	Fit indices	Δ fit indices	X^2-test	Evaluation measurement invariance
		Conscientiousness		
Conscientiousness baseline model	CFI = 0.998, TLI = 0.988, RMSEA = 0.030, SRMR = 0.009	—	—	—
Conscientiousness weak MI time	CFI = 0.986, TLI = 0.969, RMSEA = 0.048, SRMR = 0.018	Δ CFI = 0.012, Δ TLI = 0.019, Δ RMSEA = 0.018, Δ SRMR = 0.009	$X^2(4)$ = 51.01, p < .001	Weak MI does not apply

(continued)

Table A1. (continued)

Model	Fit indices	Δ fit indices	X^2-test	Evaluation measurement invariance
Conscientiousness partial weak MI time	CFI = 0.997, TLI = 0.991, RMSEA = 0.026, SRMR = 0.010	Δ CFI = 0.001, Δ TLI = 0.003, Δ RMSEA = 0.004, Δ SRMR = 0.001	$X^2(2) = 3.73$, $p = .1551$	We implemented partial weak MI and freed the lazy-indicator for the third wave
Conscientiousness strong MI time	CFI = 0.923, TLI = 0.835, RMSEA = 0.110, SRMR = 0.047	Δ CFI = 0.074, Δ TLI = 0.156, Δ RMSEA = 0.084, Δ SRMR = 0.037	$X^2(2) = 602.27$, $p < .001$	Strong MI does not apply
Conscientiousness partial strong MI time	CFI = 0.997, TLI = 0.991, RMSEA = 0.026, SRMR = 0.010	Δ CFI = 0, Δ TLI = 0, Δ RMSEA = 0, Δ SRMR = 0	Not possible, 0 df	We implemented partial strong MI and freed the lazy-indicator. It was not possible to calculate a chi^2-test, but the fit indices look good
Conscientiousness baseline group model – gender	CFI = 0.998, TLI = 0.989, RMSEA = 0.028, SRMR = 0.010	—	—	—
Conscientiousness weak MI gender	CFI = 0.998, TLI = 0.994, RMSEA = 0.020, SRMR = 0.013	Δ CFI = 0, Δ TLI = 0.005, Δ RMSEA = 0.008, Δ SRMR = 0.003	$X^2(5) = 4.72$, $p = .4507$	Weak MI does apply and fit indices look good
Conscientiousness strong MI gender	CFI = 0.998, TLI = 0.996, RMSEA = 0.017, SRMR = 0.013	Δ CFI = 0, Δ TLI = 0.002, Δ RMSEA = 0.003, Δ SRMR = 0	$X^2(2) = 1.12$, $p = .5726$	Strong MI does apply and fit indices look good
Conscientiousness baseline group model – continuing school	CFI = 0.998, TLI = 0.991, RMSEA = 0.027, SRMR = 0.009	—	—	—
Conscientiousness weak MI continuing school	CFI = 0.998, TLI = 0.994, RMSEA = 0.022, SRMR = 0.014	Δ CFI = 0, Δ TLI = 0.003, Δ RMSEA = 0.005, Δ SRMR = 0.005	$X^2(5) = 6.60$, $p = .2522$	Weak MI does apply and fit indices look good
Conscientiousness strong MI continuing school	CFI = 0.994, TLI = 0.987, RMSEA = 0.032, SRMR = 0.016	Δ CFI = 0.004, Δ TLI = 0.007, Δ RMSEA = 0.010, Δ SRMR = 0.002	$X^2(2) = 13.80$, $p = .0010$	The chi^2-test was significant, but the differences between fit indices are smaller than defined by Chen (2007) and model fit is good. Therefore, MI holds
		Perceptual speed		
Perceptual speed baseline model	CFI = 0.994, TLI = 0.989, RMSEA = 0.040, SRMR = 0.017	—	—	—
Perceptual speed weak MI time	CFI = 0.989, TLI = 0.983, RMSEA = 0.050, SRMR = 0.033	Δ CFI = 0.005, Δ TLI = 0.006, Δ RMSEA = 0.010, Δ SRMR = 0.016	$X^2(2) = 18.37$, $p < .001$	The chi^2-test was significant, but the differences between fit indices are smaller than defined by Chen (2007) and model fit is good. Therefore, MI holds
Perceptual speed strong MI time	CFI = 0.922, TLI = 0.902, RMSEA = 0.119, SRMR = 0.089	Δ CFI = 0.067, Δ TLI = 0.081, Δ RMSEA = 0.069, Δ SRMR = 0.056	$X^2(2) = 153.84$, $p < .001$	Strong MI does not apply

(continued)

Table A1. (continued)

Model	Fit indices	Δ fit indices	X^2-test	Evaluation measurement invariance
Perceptual speed partial strong MI time	CFI = 0.988, TLI = 0.983, RMSEA = 0.049, SRMR = 0.034	Δ CFI = 0.001, Δ TLI = 0, Δ RMSEA = 0.001, Δ SRMR = 0.001	$X^2(1) = 1.79$, $p = .1806$	We implemented partial strong MI and freed the first perceptual speed indicator
Perceptual speed baseline group model – gender	CFI = 0.992, TLI = 0.986, RMSEA = 0.044, SRMR = 0.017		—	—
Perceptual speed weak MI gender	CFI = 0.992, TLI = 0.988, RMSEA = 0.040, SRMR = 0.020	Δ CFI = 0, Δ TLI = 0.002, Δ RMSEA = 0.004, Δ SRMR = 0.003	$X^2(4) = 7.07$, $p = .1322$	Weak MI does apply and fit indices look good
Perceptual speed strong MI gender	CFI = 0.989, TLI = 0.986, RMSEA = 0.043, SRMR = 0.024	Δ CFI = 0.003, Δ TLI = 0.002, Δ RMSEA = 0.003, Δ SRMR = 0.004	$X^2(4) = 21.64$, $p < .001$	The chi^2-test was significant, but the differences between fit indices are smaller than defined by Chen (2007) and model fit is good. Therefore, MI holds
Perceptual speed baseline group model – continuing school	CFI = 0.991, TLI = 0.982, RMSEA = 0.048, SRMR = 0.021		—	—
Perceptual speed weak MI continuing school	CFI = 0.991, TLI = 0.987, RMSEA = 0.042, SRMR = 0.022	Δ CFI = 0, Δ TLI = 0.005, Δ RMSEA = 0.006, Δ SRMR = 0.001	$X^2(4) = 1.04$, $p = .9031$	Weak MI does apply and fit indices look good
Perceptual speed strong MI continuing school	CFI = 0.992, TLI = 0.990, RMSEA = 0.036, SRMR = 0.022	Δ CFI = 0.001, Δ TLI = 0.003, Δ RMSEA = 0.006, Δ SRMR = 0	$X^2(4) = 1.03$, $p = .9056$	Strong MI does apply and fit indices look good
		Reasoning		
Reasoning baseline model	CFI = 0.989, TLI = 0.979, RMSEA = 0.040, SRMR = 0.019		—	—
Reasoning weak MI time	CFI = 0.987, TLI = 0.981, RMSEA = 0.039, SRMR = 0.022	Δ CFI = 0.002, Δ TLI = 0.002, Δ RMSEA = 0.001, Δ SRMR = 0.003	$X^2(2) = 9.58$, $p = .0083$	The chi^2-test was significant, but the differences between fit indices are smaller than defined by Chen (2007) and model fit is good. Therefore, MI holds
Reasoning strong MI time	CFI = 0.966, TLI = 0.958, RMSEA = 0.058, SRMR = 0.035	Δ CFI = 0.021, Δ TLI = 0.023, Δ RMSEA = 0.019, Δ SRMR = 0.013	$X^2(2) = 92.15$, $p < .001$	Strong MI does not apply
Reasoning partial strong MI time	CFI = 0.985, TLI = 0.979, RMSEA = 0.041, SRMR = 0.023	Δ CFI = 0.002, Δ TLI = 0.002, Δ RMSEA = 0.002, Δ SRMR = 0.001	$X^2(1) = 11.11$, $p < .001$	The chi^2-test was significant, but the differences between fit indices are smaller than defined by Chen (2007) and model fit is good. Therefore, partial MI holds
Reasoning baseline group model – gender	CFI = 0.989, TLI = 0.980, RMSEA = 0.039, SRMR = 0.019		—	—

(continued)

Table A1. (continued)

Model	Fit indices	Δ fit indices	X^2-test	Evaluation measurement invariance
Reasoning weak MI gender	CFI = 0.986, TLI = 0.979, RMSEA = 0.040, SRMR = 0.027	Δ CFI = 0.003, Δ TLI = 0.001, Δ RMSEA = 0.001, Δ SRMR = 0.008	$X^2(4)$ = 14.90, p = .0049	The chi^2-test was significant, but the differences between fit indices are smaller than defined by Chen (2007) and model fit is good. Therefore, MI holds
Reasoning strong MI gender	CFI = 0.972, TLI = 0.965, RMSEA = 0.051, SRMR = 0.034	Δ CFI = 0.017, Δ TLI = 0.015, Δ RMSEA = 0.012, Δ SRMR = 0.015	$X^2(4)$ = 44.33, p < .001	Strong MI does not apply
Reasoning partial strong MI gender	CFI = 0.979, TLI = 0.972, RMSEA = 0.045, SRMR = 0.031	Δ CFI = 0.07, Δ TLI = 0.005, Δ RMSEA = 0.005, Δ SRMR = 0.04	$X^2(3)$ = 23.02, p < .001	The chi^2-test was significant, but the differences between fit indices are smaller than defined by Chen (2007) and model fit is good. Therefore, partial MI partial
Reasoning baseline group model – continuing school	CFI = 0.986, TLI = 0.974, RMSEA = 0.037, SRMR = 0.021		—	—
Reasoning weak MI continuing school	CFI = 0.987, TLI = 0.980, RMSEA = 0.033, SRMR = 0.023	Δ CFI = 0.001, Δ TLI = 0.006, Δ RMSEA = 0.004, Δ SRMR = 0.002	$X^2(4)$ = 3.19, p = .5273	Weak MI applies
Reasoning strong MI continuing school	CFI = 0.984, TLI = 0.981, RMSEA = 0.032, SRMR = 0.025	Δ CFI = 0.003, Δ TLI = 0.001, Δ RMSEA = 0.001, Δ SRMR = 0.002	$X^2(4)$ = 7.02, p = .1348	Strong MI applies

Note. Own calculations based on NEPS SC3: 12.1.0.