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Personality, competencies, and life outcomes: results from the German PIAAC longitudinal study

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Abstract

The present paper investigates the power of personality to predict important life outcomes in the context of the Programme for the International Assessment of Adult Competencies (PIAAC). On the most global level, personality can be described by the Big Five dimensions, extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience. These five dimensions were assessed in the German PIAAC longitudinal study ($N = 4122$) and can thus be directly related to the central competence and outcome indicators measured in PIAAC. In a first step, we report the relationships between the Big Five dimensions and the basic competencies literacy and numeracy. In a second step, we investigate the extent to which the five personality dimensions can contribute to explaining six important life outcomes, above and beyond competencies and sociodemographic characteristics. Our results indicate that personality is substantially related to all six life outcomes. The portion of variance explained by personality was similar to, and sometimes larger than, that explained by competencies. After adjusting for competencies, personality was incrementally predictive of life satisfaction and health, in particular, and, to a lesser extent, of educational attainment, employment status, and income. The only outcome of which personality was not incrementally predictive over and above competencies was participation in continuing education. Overall, these findings highlight the merit of including measures for the Big Five personality domains in upcoming cycles of PIAAC.

Keywords: PIAAC, Cognitive skills, Competencies, Personality, Health, Income, Well-being

Background

Cognitive skills, such as literacy and numeracy, are undoubtedly powerful predictors of important life outcomes such as educational attainment, income, and health (Herrnstein and Murray 1994). However, during the last decade, other traits besides cognitive skills have emerged as potent predictors of life outcomes. These traits—often collectively referred to as "non-cognitive skills"—include personality, motivation, interests, and beliefs.

The Nobel Prize-winning economist James Heckman was among the first to champion the role of non-cognitive skills in shaping important life outcomes. In an influential article (Borghans et al. 2008; see also Heckman et al. 2006), he and his co-authors urged that

"new studies should incorporate validated personality, IQ, and preference measures, as well as outcome measures" (p. 1037). In recent years, many researchers and studies have heeded this call. Influential national surveys, such as the German Socio-Economic Panel (SOEP), the German National Educational Panel Study (NEPS), Household, Income and Labour Dynamics in Australia (HILDA), and the UK Household Longitudinal Study (UKHLS), and international surveys, such as the World Values Survey (WVS) and the International Social Survey Programme (ISSP), have included measures of personality and other non-cognitive skills in their core questionnaires.

Results of these surveys and earlier landmark studies (e.g., Roberts et al. 2007; see Ozer and Benet-Martínez 2006 for overviews) attest to the predictive power of non-cognitive skills such as the Big Five personality traits, dispositional optimism, or locus of control for a broad range of important life outcomes. For example, several studies have shown that the personality dimensions conscientiousness and dispositional optimism are related to a person's health, including morbidity and even mortality (Allison et al. 2003; Arthur and Graziano 1996; Bogg and Roberts 2004; Rasmussen et al. 2009). Other studies have found that individuals with a more external locus of control and low levels of emotional stability report lower levels of life satisfaction (Rammstedt 2007) and that the marriages of more conscientious individuals last longer (Roberts and Bogg 2004). Personality also affects job performance (Hogan and Holland 2003) and income (Judge et al. 2012).

Motivated by Heckman's call and by these encouraging findings, large-scale studies conducted under the auspices of the Organisation for Economic Co-operation and Development (OECD) have become increasingly interested in including personality and other non-cognitive skills in addition to the classical cognitive skill measures. For example, the OECD is currently setting up a Longitudinal Study of Social and Emotional Skills. The inclusion of non-cognitive skill measures is also progressing in the well-established Programme for International Student Assessment (PISA). Finally, within the scope of the Programme for the International Assessment of Adult Competencies (PIAAC), an expert group has been established to identify the most central non-cognitive skills to be included in the upcoming PIAAC cycle, which is scheduled to begin in 2018.

With this renewed interest in non-cognitive skills, the study of human abilities has come full circle. Several early ability theorists prominently argued that non-cognitive skills (or "non-ability traits") should be studied alongside cognitive skills, and attempted to integrate the former into their theoretical models of human abilities. For example, Wechsler (1950) suggested the inclusion of what he called "non-intellective" traits into IQ tests that were then already well-established; his view was that such traits might offer added value in the prediction of real-life performance. His contemporary, Vernon (1950, p. 47), included an "X" factor along with a cognitive Spearman-type g factor in his model of the structure of "educational abilities", under which, among other things, he subsumed personality and interests (although he did not further specify which non-cognitive factors he deemed crucial). Yet the assessment and theory of non-cognitive traits has long lagged behind that of achievement and intelligence, and even the aforementioned early proponents did not follow up on their own arguments concerning non-cognitive skills, devoting little effort to studying them in their own research agenda. For this reason, non-cognitive skills appear to somehow have fallen into oblivion among

ability researchers, especially in the wake of advances in cognitive testing and the publication of influential studies on the potency of cognitive skills in predicting life outcomes, such as Herrnstein and Murray's (1994) famous "bell curve". It so occurs that surprisingly little theoretical work, let alone large-scale empirical efforts, have been devoted to the interface of cognitive and non-cognitive skills—with some more recent exceptions, most notably Ackerman's (1996) PPIK theory (intelligence-as-process, personality, interests, and knowledge) and a book-length treatment of the topic by Chamorro-Premuzic and Furnham (2005).

Partly owing to this long-standing dearth of theoretical work, the definition of "non-cognitive skills", as well as their relation to cognitive skills, remain rather vague. The term is meant as a catchphrase describing a broad range of potentially relevant skills other than the "cognitive skills" measured by standardized achievement and IQ tests. So far, however, researchers have not reached any clear consensus as to which specific skills should be included under this umbrella term. In the absence of a clear definition, most extant surveys have included those non-cognitive skills that promised to be related to the central outcomes of interest in these surveys. Thus, the set of constructs mostly follows the specific intention of the study in question. Despite this definitional uncertainty, nearly all of these surveys have included the major dimensions of personality, the so-called Big Five. The Big Five aim to describe an individual's personality on the most global level with five largely independent dimensions (De Raad 2000; Goldberg 1990; John et al. 2008). These dimensions are extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience. Also within the above-mentioned expert group charged with identifying the most central non-cognitive skills to be included in the PIAAC study, the only point on which a clear consensus has been reached is that the Big Five personality dimensions should be included.

In summary, a growing body of evidence on personality and important life outcomes has yielded a key insight that is of potentially high relevance to public policy and interventions, namely that, even though the importance of cognitive skills in predicting key indicators of life success is beyond doubt, non-cognitive skills such as personality are often equally potent—and sometimes even more potent—predictors of these outcomes (Roberts et al. 2007; Heckman and Kautz 2012). This view is further reinforced by the finding that cognitive abilities and personality are substantially related (Rammstedt et al. 2016). This confounding of allegedly "pure" measures of cognitive skills with non-cognitive skills has led some researchers (e.g., Heckman and Kautz 2012; Borghans et al. 2011) to contend that many existing analyses of the purported effects of cognitive skills on life outcomes may overestimate the effects of cognitive skills if these analyses do not control for personality. Consequently, these researchers have called for further research that pits the predictive power of cognitive and non-cognitive skills against each other.

The present study

Despite the important empirical advances made in research on the relationship between non-cognitive skills, such as personality traits, and life outcomes during the past decade, this body of evidence is still somewhat limited by the heavy reliance on largely North American samples, and especially on samples that are often small and non-representative. Furthermore, extant studies have used widely varying instruments to assess

cognitive and/or non-cognitive skills, many of which were not well validated. Finally, most studies so far have not jointly considered non-cognitive and cognitive skills and tested their predictive power against each other. In the present study, therefore, we aim to replicate and extend previous findings on the linkages between non-cognitive skills, cognitive skills, and life outcomes, drawing on the data from the German PIAAC and its longitudinal extension.

PIAAC aims to investigate the acquisition and loss of adult competencies, skill usage, and the relations between these competencies and key indicators of life success. The PIAAC data are particularly well suited for our present study, as they offer high-quality measures of cognitive skills (competencies), non-cognitive skills (personality dimensions), and a broad range of important life outcomes (e.g., labor market participation, income, and health) in a large-scale representative sample of the adult population in Germany.

In line with the main research goals of PIAAC, the specific purpose of our present study is twofold. First, we repeat and briefly report previous analyses (Rammstedt et al. 2016) of the relationships between the Big Five personality dimensions and two key adult competencies assessed in PIAAC, namely literacy and numeracy. In so doing, we aim to show that cognitive and non-cognitive skills are related (or, put differently, confounded; Borghans et al. 2011). Second, and most importantly, we investigate the extent to which the five personality dimensions can contribute—above and beyond basic cognitive skills—to explaining central life outcome variables measured in PIAAC. To this end, we compare the effects of separately analyzed non-cognitive skills and cognitive skills assessed in PIAAC on six indicators of life success, namely health, life satisfaction, educational attainment, labor force participation, participation in continuing education, and income. In addition, we investigate whether personality can explain additional variance in these life outcomes, even after adjusting for the effects of competencies (incremental validity). As the present study is based on a cross-sectional approach no causal interpretations regarding the direction of the associations between non-cognitive skills and the investigated life success indicators can be drawn.

Methods

Sampling, method, and participants

Data for the present study come from the German PIAAC survey (Rammstedt et al. 2015) and the German PIAAC longitudinal study (PIAAC-L; see Rammstedt et al. 2017), a follow-up survey of the same sample. The PIAAC program compares cognitive skills—such as the two key adult competencies literacy and numeracy—across a large number of (mainly OECD) countries. The target population in the German PIAAC study, conducted in 2012, comprised adults (aged between 16 and 65 years) who were randomly selected from local population registers in randomly selected municipalities across Germany. Participation in PIAAC was voluntary; an incentive of 50 euros was offered upon participation in the survey, which comprised a personal interview (average duration: 45 min) and a cognitive assessment lasting approximately 60 min. Zabal et al. (2014) provide a detailed description of the sampling procedure and the technical implementation.

In PIAAC-L, a German follow-up study to PIAAC, 4122 of the original 5465 PIAAC participants in Germany were re-interviewed in 2014. Participation was voluntary and

incentivized by a small amount of money (usually 25 euros). For a detailed description of the study design and the technical implementation of PIAAC-L, see Zabal et al. (2016) and Steinacker et al. (2016). For the present analyses, we combined data from the 2012 wave of the German PIAAC and the 2014 follow-up survey.[1]

Measures and procedure

For the present analysis, we investigated the following variables from PIAAC 2012 and the 2014 PIAAC-L follow-up:

Big Five personality dimensions

In the 2014 PIAAC-L follow-up, respondents completed a 15-item short version of the Big Five Inventory (BFI) originally developed for use in the German Socio-Economic Panel (SOEP; Schupp and Gerlitz 2014). This questionnaire contains three items per Big Five dimension, to be answered on a seven-point scale ranging from *does not apply* (1) to *applies fully* (7).

Competencies

Our cognitive skill measures in PIAAC comprised two key adult competencies: literacy and numeracy. Literacy refers to the ability to understand and use information from written texts in a variety of contexts to achieve goals and develop knowledge and potential. Numeracy is defined as the ability to use, apply, interpret, and communicate mathematical information and ideas (see OECD 2013). Both competencies represent acquired skills, resembling the definition of Cattell's "crystallized intelligence" (Gc) or Hebb's "Intelligence B" (see Ackerman 1996, for a Discussion of these models). were assessed using a multistage adaptive testing design. For each participant, 10 plausible values were estimated for each competency domain (for details of the design and the IRT scaling process in PIAAC, see OECD 2013). All our models involving the competencies were run separately for each of the ten plausible values per domain. For the correlational analyses, we then averaged the results across these ten models per domain. For the regression analyses, the first plausible value was used per domain. Deviating findings for the other plausible values are reported where applicable.

Important life outcomes

Six central indicators of life success from the domains health and well-being, education, and work were selected from the PIAAC and PIAAC-L variables.

Health In PIAAC, respondents rated their subjective general health with a single item on a five-point scale ranging from *very good* to *bad* (I_Q08).

Life satisfaction In PIAAC-L, satisfaction with 11 different life domains (work, leisure, dwelling, sleep, health, housework, childcare, family care, schooling, personal income, household income; pzuf) and with life in general (pzule1_14) was assessed. Respondents

[1] GESIS-Leibniz Institute for the Social Sciences, German Socio-Economic Panel (SOEP) at DIW Berlin & LIfBi-Leibniz Institute for Educational Trajectories (2016). PIAAC-Longitudinal (PIAAC-L), Germany. *GESIS Data Archive*, Cologne. ZA5989 Data file Version 1..0, doi:10.4232/1.12487.

answered these items on an 11-point rating scale ranging from 0 (*totally unsatisfied)* to 10 (*totally satisfied*). We computed an overall life satisfaction index by taking the mean across all twelve items. Cronbach's alpha for the twelve items was .81.

Educational attainment Respondents' highest level of education was assessed with two separate questions (highest general education and highest vocational education qualification in the categories of the German education system), which were then mapped to the levels 0–6 of the International Standard Classification of Education (ISCED) 1997 based on the PIAAC variable PIAAC: B_Q01a.[2]

Labor force participation All respondents were asked in PIAAC, and again in PIAAC-L, to report whether they were currently employed and, if not, what their current main activity was. For the present analyses, we used the corresponding question of the PIAAC-L assessment (perw). In 2014, 46% of the sample reported that they were employed full-time, 16% reported that they were employed part-time, 4% reported that they were undergoing vocational training, 7% reported that they were marginally employed, and 27% reported that they were not employed. For the present analyses, we generated a dichotomous variable indicating whether or not a respondent was employed full-time (1 *in full-time employment*, 0 *not in full-time employment*[3]).

Participation in continuing education All PIAAC respondents were asked whether they had participated in any form of continuing education and training during the past 12 months, including distance learning (B_Q12a), on-the-job training (B_Q12c), workshops or seminars (B_Q12e), or other courses or private tuition (B_Q12g). For our analyses, we generated a dichotomous variable indicating whether a respondent participated in any continuing education and training (53%) or not (47%) during the past 12 months.

Income For the subsample of full-time employed individuals, personal income was estimated in PIAAC based on self-reported monthly income in euros (EARNMTHALL). We logarithmized the income variable for the present analyses.

Sociodemographic control variables

In addition to these predictors and outcome variables, we included key sociodemographic characteristics as statistical control variables. In particular, we controlled for the respondent's age in years (based on lgeb_14), gender (0 *male*; 1 *female*; lsex_14), their highest level of education (ISCED 0-6; based on B_Q01a),[4] and their migration status (0 *born in Germany*; 1 *not born in Germany*; lgebd_14).

For some of the analyses, it was appropriate to analyze only subsamples instead of the full sample. Specifically, for educational attainment, employment status, and participation in continuing education as outcomes, we focused on a subsample comprising only those respondents who reported as their main activity (paus1_14) that they were not

[2] Foreigners who obtained their qualifications in another country were asked to report the nearest German equivalent. If this was not possible, they were excluded from analyses ($n = 41$).

[3] Besides part-time employed respondents, this category includes those who were unemployed or not in the labor force.

[4] The highest level of education was not controlled when education was the dependent variable.

Table 1 Associations between the Big Five scales and basic competencies (literacy and numeracy)

	Literacy	Numeracy
Extraversion (linear)	−.05**	−.06***
Agreeableness (linear)	−.02	−.03
Conscientiousness (linear)	−.10***	−.08***
Emotional stability (linear)	.11***	.14***
Openness (linear)	.05*	.05***
Extraversion (quadratic)	−.01	−.01
Agreeableness (quadratic)	−.05**	−.04*
Conscientiousness (quadratic)	−.03*	−.05**
Emotional stability (quadratic)	−.06***	−.06***
Openness (quadratic)	−.06***	−.07***

Correlations are Fisher-*Z* transformed and averaged across the ten plausible values, * p < .05, ** p < .01, *** p < .001, *N* = 3757; the correlations between the two abilities range between .86 and .87

presently in education. For employment status and participation in continuing education, we additionally excluded retired persons.[5] For income as an outcome, our subsample included only respondents working full-time (perw_14) and excluded respondents who were employed part-time or retired. Descriptive statistics for these variables are reported in Appendix Tables 4 and 5.

Results

Personality and basic competencies

In a first step, we examined the degree to which the Big Five dimensions were related to the basic competencies literacy and numeracy. As a recent study (Major et al. 2014) demonstrated that there are not only linear but also quadratic associations between personality and cognitive ability, we included both linear and quadratic terms in our models.

We will discuss effects that are statistically significant ($\alpha = .05$) and practically meaningful. There are no clear cut-off criteria for practical meaningfulness and we decided discuss all standardized regression coefficients that exceed .05, thus explaining more than .25% of the unique variance.[6][7]

As can be seen in Table 1, the Big Five domains conscientiousness, emotional stability, extraversion, and openness showed substantial linear associations with both numeracy and literacy. emotional stability and openness were positively related to both cognitive domains, indicating that more emotionally stable and open respondents possess, on average, slightly higher numeracy and literacy skills than their less emotionally stable and open counterparts. By contrast, conscientiousness was negatively associated with both competencies, indicating that more conscientious respondents have, on average, lower numeracy and literacy skills than less conscientious respondents.

In addition to these linear effects, emotional stability and openness were also quadratically related to numeracy and literacy (see Fig. 1a–h). As the figures show, for both

[5] To differentiate between retired and non-retired persons, a variable was derived based on spelltype (=8 for the retired) and begin (<2014 for the retired).

[6] This cut-off criteria can be seen a compromise between Rosenthal (1990) who suggests that even .10% explained variance can be meaningful and other (e.g. Rasch et al. 2010) who suggest that 1% explained variance is only a small effect.

[7] Rammstedt et al. (2016) discuss these analyses in greater detail.

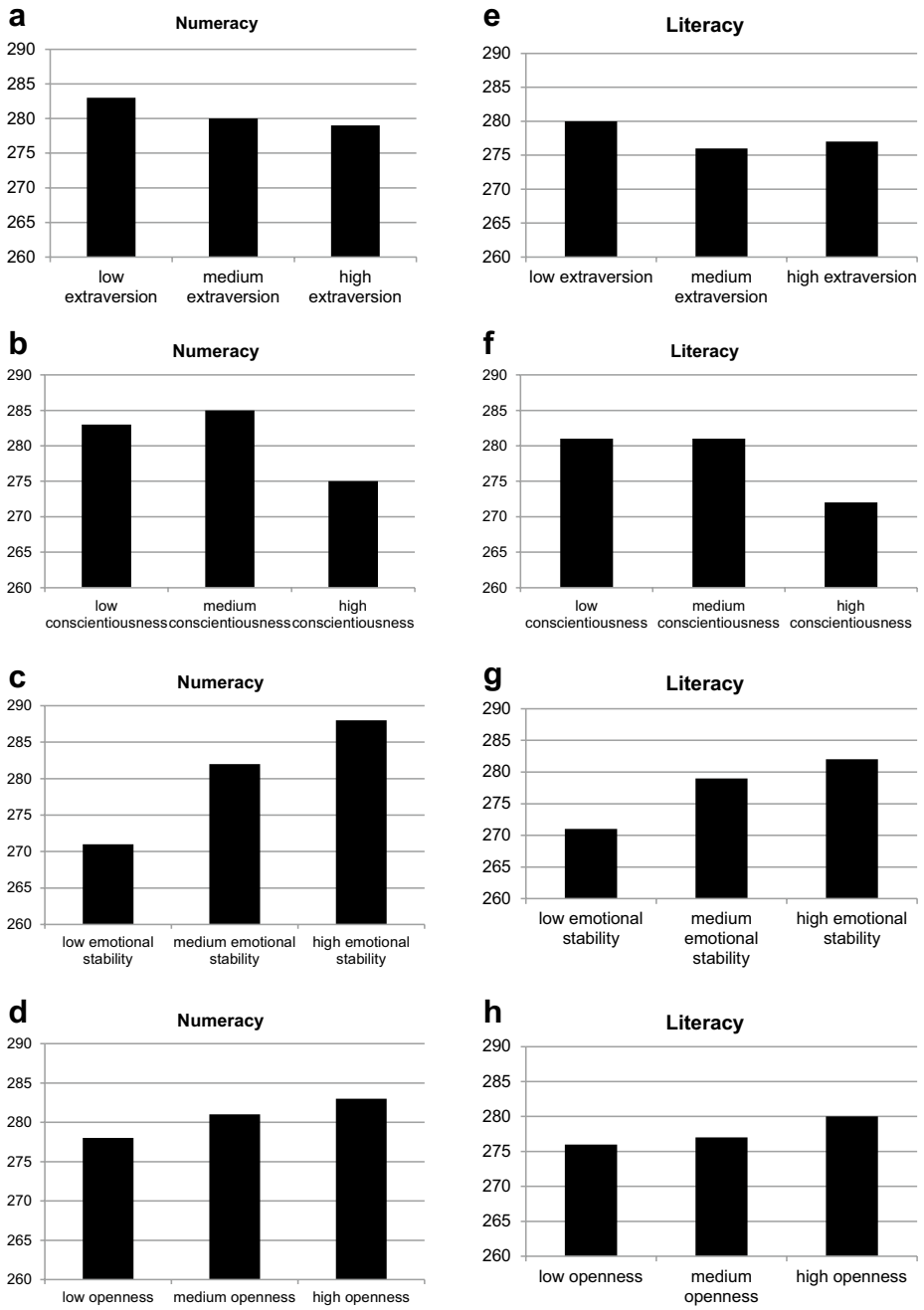

Fig. 1 **a**–**h** Associations between the Big Five personality domains and numeracy and literacy (means based on tertile splits)

cognitive domains and for both personality domains the positive association between emotional stability and openness with both numeracy and literacy was primarily caused by low competence levels of persons low on emotional stability and openness, respectively, whereas persons with intermediate and high levels of these personality domains differed, on average, less in their competencies.

Table 2 Relationships between personality, numeracy, and important life outcomes

Model	Highest level of education (ISCED 1997)[a]			Employment status (full-time)[a,b]			Continuing education[a,b]		
	I	II	III	I	II	III	I	II	III
Extraversion (linear)	−.09***		−.04*	.01		.02	−.02		−.01
Agreeableness (linear)	−.04*		−.03	−.12***		−.12***	−.05*		−.05
Conscientiousness (linear)	−.03		−.01	.17***		.18***	.03		.04
Emotional stability (linear)	.12***		.05**	.12***		.11***	.06*		.04
Openness (linear)	.14***		.10***	−.02		−.02	.01		.01
Extraversion (quadratic)	−.02		−.01	.05		.05	−.04		−.04
Agreeableness (quadratic)	−.04*		−.04*	−.02		−.01	.02		.02
Conscientiousness (quadratic)	−.07***		−.03	.01		.02	−.03		−.02
Emotional stability (quadratic)	−.03		−.02	−.01		−.01	−.02		−.02
Openness (quadratic)	−.01		.00	−.01		−.01	.01		.02
Numeracy[d]		.52***	.50***		.15***	.16***		.18***	.18***
Age	.16***	.23***	.22***	−.15***	−.10***	−.13***	−.07**	−.03	−.04
Gender (women)	−.01	.03*	.04*	−.53***	−.52***	−.52***	−.03	−.02	−.01
Education	—	—	—	.27***	.20***	.20***	.34***	.26***	.26***
Migration (migrant)	−.09***	.01	.01	−.03	−.01	−.00	−.08***	−.06*	−.06*
N	3174	3174	3174	2868	2868	2868	2800	2800	2800
R^2	.08	.29	.30	.31[c]	.29[c]	.32[c]	.13[c]	.14[c]	.15[c]

[a] Only respondents who have completed their education (paus1_14)

[b] Only respondents who are not retired

[c] Pseudo R^2

[d] Using different plausible values did not change the pattern of results. The regression coefficients for numeracy maximally changed by Δ = .05. Detailed results for all ten plausible values are presented in Additional file 1: Table S1

* p < .05, ** p < .01, *** p < .001

Overall, the pattern of both the linear and the quadratic correlations between personality and competencies was impressively homogeneous for the two cognitive domains. The correlation between numeracy and literacy was $r = .87$ on average and ranged between $r = .86$ and $r = .87$ across the ten plausible values.

Personality and important life outcomes

In a second step, we investigated the degree to which the Big Five domains are related to important life outcomes measured in PIAAC. To investigate these relationships, we ran linear and logistic regression analyses with three different models per outcome indicator. In the first model, we estimated linear and quadratic associations of the Big Five domains with the six life outcomes. In the second model, we estimated the associations between the basic competencies (literacy and numeracy) and the six life outcomes. Finally, in our third model, we jointly considered the effects of personality and competencies in order to test the degree to which the personality dimensions explained variance over and above the competencies (incremental validity). In all three models, we controlled for the sociodemographic variables age, gender, educational attainment,[8] and migration status. The standardized regression coefficients (β) are shown in Tables 2 and 3. The corresponding results for literacy are provided in Appendix Tables 6 and 7 because the

[8] The highest level of education was not controlled when education was the dependent variable.

Table 3 Relationships between personality, numeracy, and important life outcomes

Model	Income (log)[a,b]			Health			Life satisfaction		
	I	II	III	I	II	III	I	II	III
Extraversion (linear)	.03		.04	.02		.02	.01		.02
Agreeableness (linear)	−.02		−.01	.05**		.05**	.09***		.09***
Conscientiousness (linear)	−.02		.00	.04*		.04*	.13***		.14***
Emotional stability (linear)	.01		.00	.21***		.20***	.32***		.31***
Openness (linear)	−.12***		−.12***	−.01		−.01	.00		.00
Extraversion (quadratic)	−.02		−.03	.00		.00	−.01		−.01
Agreeableness (quadratic)	.05*		.05*	.00		.00	.02		.02
Conscientiousness (quadratic)	−.04		−.03	−.02		−.02	.00		.01
Emotional stability (quadratic)	−.02		−.03	−.04**		−.04*	−.02		−.02
Openness (quadratic)	−.07**		−.07**	−.02		−.01	−.03		−.02
Numeracy[c]		.14***	.14***		.12***	.10***		.13***	.11***
Age	.22***	.25***	.25***	−.34***	−.30***	−.31***	−.12***	−.06***	−.09***
Gender (women)	−.13***	−.13***	−.11***	.00	−.01	.01	.03*	.01	.04**
Education	.28***	.20***	.21***	.14***	.10***	.09***	.11***	.09***	.06**
Migration (migrant)	−.01	.00	.01	−.02	−.01	.00	−.04**	−.04*	−.02
N	1626	1626	1626	3716	3716	3716	3717	3717	3717
R^2	.19	.18	.20	.16	.11	.17	.17	.04	.17

Values are standardized regression coefficients, * p < .05, ** p < .01, *** p < .001

[a] Only respondents who are not retired

[b] Only respondents who are employed full-time

[c] Using different plausible values did not change the pattern of results. The regression coefficients for numeracy maximally changed by Δ = .05. Detailed results for all ten plausible values are presented in Additional file 1: Table S1

resulting coefficients in the same models for literacy were highly similar to those for numeracy.

One of the most central outcome variables of PIAAC is educational attainment. As shown in the first model in Tables 2 and 3, the highest level of education was substantially related to personality, which—together with the control variables—explained 8% of the overall variance. Higher emotional stability and openness were related to higher educational attainment. extraversion, by contrast, was negatively related to educational attainment. conscientiousness showed a negative quadratic relationship with educational attainment, which means that respondents with lower levels of conscientiousness reported lower educational attainment. Respondents with average levels of conscientiousness had the highest educational attainment, whereas an above-average level of conscientiousness did not bring any additional advantage (see Fig. 2a).

Educational attainment is known and expected to be strongly related to the cognitive abilities of a person. Therefore, it is not surprising that, as shown in our second model in Tables 2 and 3, numeracy was highly related to the highest level of education, explaining 29% of the variance.

In our third model, we compared the relationship between personality and cognitive competencies on the one hand and educational attainment on the other. Compared to

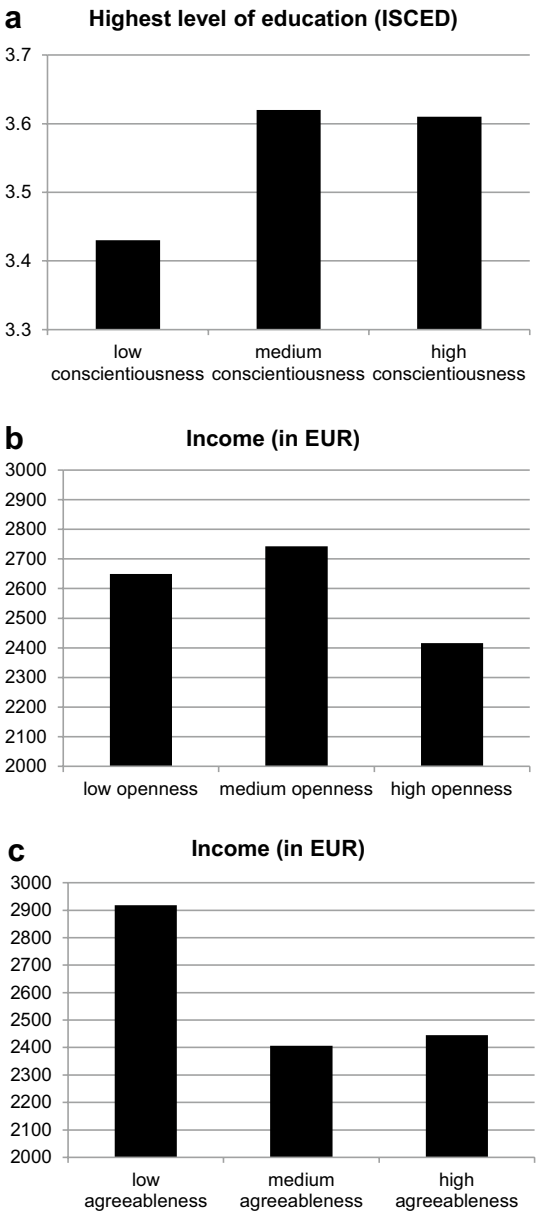

Fig. 2 Quadratic associations between the Big Five personality domains and educational attainment (**a**), and income (**b**, **c**) (means based on tertile splits)

Model II (competencies only), jointly considering personality and competencies slightly increased the explained variance to 30%. In addition, the linear negative associations between extraversion and educational attainment, the positive effect of emotional stability on educational attainment, and the quadratic association between conscientiousness and educational attainment in Model I diminished when numeracy was taken into account. Thus, after adjusting for numeracy, only the personality dimension openness substantially contributed to explaining additional variance in educational attainment.

Our second outcome variable is labor force participation (full-time employment). As can be seen from Model I, being employed full-time was positively related to

conscientiousness and emotional stability and negatively related to agreeableness. Overall, Model I, which contained the personality dimensions and the control variables, explained 31% of the variance in labor force participation. By contrast, the competencies (Model II) explained only 29% of the variance. Taking both the non-cognitive and the cognitive skills into account (Model III) did not substantially change the associations observed in the preceding models, but it increased the variance explained to 32%.

In PIAAC, participation in continuing education is regarded as a central indicator for the maintenance and broadening of skills over the life course. Therefore, a clear positive association between the skills assessed in PIAAC and participation in continuing education is hypothesized and supported by the PIAAC data (OECD 2013). Here, we investigated the degree to which participation in continuing education was also related to non-cognitive skills (i.e., personality) in addition to cognitive skills (i.e., the competencies). Indeed, our analyses revealed a substantial positive association between participation in continuing education and a person's level of emotional stability (Model I), indicating that emotionally more stable persons have a stronger tendency to participate in continuing education. This model explains 13% of the variance. A quite similar amount of variance could be explained when only numeracy skills rather than the personality domains were taken into account (14%, Model II) or when both numeracy and personality were taken into account (15%, Model III).

Income is another central outcome variable in PIAAC. Using Mincer regressions (Mincer 1974), we were able to show in earlier studies (Klaukien et al. 2013) that literacy and, in particular, numeracy skills substantially added to the prediction of a person's income. These results were largely replicated in our Model II.

Recent studies based on large Anglo–American and British samples have provided initial evidence that income is related to an individual's personality (e.g., Judge et al. 2012; Heineck 2014; Mueller and Plug 2006). In particular, these studies have shown that low agreeableness and high openness are associated with higher income. In addition, previous studies have indicated that the negative association between agreeableness and income, in particular, is curvilinear—that is, the agreeableness-income relationship is steeper at lower levels of agreeableness (Judge et al. 2012). Gender also seems to play an important role in the personality-income relationship. Previous results have indicated that the negative effect of agreeableness on income holds especially for men but not for women (Judge et al. 2012).

Results from our own analyses using the total sample comprising both genders did not replicate previous findings on the positive association between openness and income (e.g., Judge et al. 2012; Heineck 2014; Mueller and Plug 2006). On the contrary, we found a significant negative association between openness and income, indicating that persons who are higher on openness earn, on average, less than persons who are lower on openness. In addition to this linear association, there was a quadratic relationship between openness and income. Persons with higher levels of openness had the lowest average income, while those with an intermediate level of openness had the highest average income (see Fig. 2b). However, the negative quadratic association between agreeableness and income reported by Judge et al. (2012) could be replicated in our data. As can be seen in Fig. 2c, agreeableness showed a quadratic association with income,[9] indicating

[9] With a regression coefficient of .05, it is thus just below our self-imposed threshold of >.05.

that persons who are low in agreeableness have by far the highest average income, while persons with intermediate levels of agreeableness earn the least. In additional analyses, we were able to show that this curvilinear negative association between agreeableness and income tended to be more pronounced in men (unstandardized $b = .04$, $p = .031$) than in women (unstandardized $b = .01$, *ns*).

In our third model, we directly compared the strengths of the associations between numeracy and personality and income when mutually controlling for each other. As shown in Tables 2 and 3, the linear and quadratic effects of openness and agreeableness and of numeracy on income are more or less additive, explaining a total of 20% of the variance in income. Because income is usually predicted by means of a Mincer regression (Mincer 1974) in economic research, we also replicated our analysis with this method. Results from these alternative models (not shown) did not differ substantially.

Our final two outcomes were self-rated health status and life satisfaction. The non-cognitive skills investigated (Model I) clearly contributed to explaining self-rated health (16%). emotional stability ($\beta = .21$) was substantially and strongly related to self-rated health, with emotionally stable persons reporting better health, on average. Cognitive skills (Model II) also contributed to explaining self-rated health. However, this model, which included only numeracy and the control variables, explained markedly less variance (11%) than Model I. As can be seen from Model III, the combined effects of personality and numeracy remained more or less unchanged, and explained 17% of the overall variance in self-rated health.

As one of the most crucial indicators of life success, we investigated overall life satisfaction. An individual's level of life satisfaction depends not only on external circumstances but is also related to his or her personality. Specifically, individuals who are more emotionally stable, extraverted, conscientious, and agreeable tend to experience greater life satisfaction (e.g., Steel et al. 2008). The present results, where sociodemographic effects were controlled for in parallel, largely confirmed these findings. As regards overall life satisfaction, the more emotionally stable ($\beta = .32$), conscientious ($\beta = .13$), and agreeable ($\beta = .09$) a person was, the higher he or she rated their life satisfaction. Overall personality and the sociodemographic control variables together explained 17% of the variance in life satisfaction (Model I). In contrast, the model that included only numeracy and the control variables explained only 4% of this rating (Model II). Combining non-cognitive and cognitive skills in Model III did not alter the amount of explained variance compared to Model I, which included only the personality dimensions (17%).

Taken together, our results indicate that the Big Five personality dimensions contribute substantially to explaining central indicators of life success in PIAAC. However, their explanatory power differed markedly across the outcomes under investigation. Whereas the competencies (i.e., numeracy and literacy) were much more potent than non-cognitive skills (i.e., personality) in predicting educational attainment, for example, the opposite was the case for life satisfaction and, to a lesser extent, for self-perceived health. Here, the personality dimensions clearly outperformed the competencies in terms of explanatory power. For other outcomes, such as participation in continuing education or income, the non-cognitive and the cognitive skills were highly comparable with regard to their predictive power.

Discussion

The present study aimed to elucidate the impact of non-cognitive skills on central outcomes measured in PIAAC. We therefore investigated the relations between the personality domains of the Big Five approach to personality and (a) the cognitive skills assessed in PIAAC, namely literacy and numeracy, and (b) central economic and social outcomes. For the latter analyses, we compared the explanatory power of the non-cognitive skills to that of the adult competencies assessed in PIAAC.

As previously discussed (Rammstedt et al. 2016), the PIAAC-L data revealed that personality was substantially related to both numeracy and literacy. We were able to replicate the typically found positive linear associations between emotional stability and openness and cognitive skills and the negative association between conscientiousness and cognitive skills (Ackerman and Heggestad 1997; DeYoung 2011; Chamorro-Premuzic and Furnham 2005; Von Stumm and Ackerman 2013). Results of the quadratic analyses demonstrated that the results for emotional stability and openness were primarily triggered by comparatively low performance in the competency measures of persons who were low on emotional stability or openness, respectively. Together with other recent large-scale studies (e.g., Lechner et al. 2016), our results suggest that the relationships between cognitive and non-cognitive skills—here in particular: personality and crystallized intelligence, or Gc—may be stronger and more systematic than either Ackerman (1996) or Chamorro-Premuzic and Furnham (2005) envisioned in their important theoretical treatments. Whereas Ackerman (1996) looked at only a "small set of personality factors" (p. 238) that appeared to be related to cognitive skills because there was little evidence to suggest otherwise, we contend that it may be worth reconsidering the personality–intelligence interface in the light of emerging large-scale findings. This may lead to stronger theories explaining the acquisition of cognitive and non-cognitive skills across the life span, as well as how they co-shape important life outcomes.

However, the focus of our study was on the relationships between the Big Five personality domains and six important life outcomes measured in PIAAC. Most of the associations between personality and important life outcomes in our analyses are largely in line with previous findings reported in the literature, in which conscientiousness and emotional stability, in particular, have emerged as powerful predictors of a broad range of life outcomes (Roberts et al. 2007; Ozer and Benet-Martínez 2006). Only the repeatedly reported positive association between openness and income (see Ng et al. 2005) did not replicate in our analyses of the PIAAC data. On the contrary, our analyses revealed a substantial negative association between openness and income. While the reasons for this divergence are unclear, some findings have suggested that the openness–income association is culture- or country-sensitive. For example, based on a large Dutch sample, Gelissen and de Graaf (2006) also reported that openness was negatively related to earnings among men (but unrelated among women). Similarly, based on the comprehensive data of the German SOEP, Heineck and Anger (2010) found a negative association between openness and hourly earnings among men (but a positive association among women). Finally, Danner and Rammstedt (2015) compared the association between openness and income in 19 countries worldwide based on the International Social Science Survey Program (ISSP) data. Their results indicated that both the size and the direction of the

association differed markedly across the countries. In the US and Ireland, openness was indeed positively related to income. By contrast, in Germany, as in the present study, and in several other countries, for example Latvia, the openness-income association was negative. Taken together, the associations between personality and life outcomes found in the present study largely support the current state of research.

Previous research in the context of PIAAC has investigated the degree to which the different life outcomes can be explained by cognitive skills. In the present study, we aimed to investigate the extent to which these life outcomes can be incrementally—above and beyond cognitive skills—explained by non-cognitive skills. Therefore, we examined the effects of personality on these outcomes, controlling for sociodemographic characteristics, and we compared these models to models that included the competencies assessed in PIAAC, namely numeracy and literacy. Our results indicate that the Big Five personality domains substantially contribute to explaining variance in all six life outcomes investigated. After adjusting for the effects of the competencies, personality could, in all cases, explain an additional proportion on the variance. However, the strength of these contributions differed markedly across the different outcomes investigated. For the economic outcome variables, income and employment status, the incremental validity of personality above and beyond the competencies was comparatively low, ranging from 1 to 3%. Also in the case of educational attainment and participation in continuing education, a greater portion of the variance was explained by the competencies than by the personality dimensions. By contrast, life satisfaction and, to a lesser extent, self-rated health were more strongly predicted by personality than by the competencies. The reasons for these differences in the predictive power of personality across different types of outcomes are currently unclear, but two possible explanations readily come to mind. First, it might be argued that personality factors may simply have a stronger bearing on subjective outcomes because they operate within the same domain of psychological processes. Second, building on the idea of Brunswik's construct symmetry (see Wittmann 1988), it may be argued that personality factors are measured on a high aggregation level that corresponds more closely to that of life satisfaction self-rated health that to that of more specific outcomes such as income; according to Brunswik symmetry, stronger relationships can be expected between constructs that are measured on the same aggregation level than among constructs measured at different aggregation levels. Future research is needed to disentangle these explanations.

In sum, the present study showed that, for large-scale survey programs such as PIAAC, non-cognitive skills—in this case, personality dimensions—are substantially related to important life outcomes and can contribute to explaining these outcomes over and above cognitive skills, although this contribution varies across outcomes. These results attest to the usefulness of including measures of non-cognitive skills in future cycles of these large-scale surveys. This is all the more true given the growing availability of well-validated short-scale measures for these concepts.

Additional file

Additional file 1. Additional tables.

Appendix

See Tables 4, 5, 6 and 7.

Table 4 Descriptive statistics for continuous variables

	Mean	Standard deviation	Range	No. items	Reliability estimate
Extraversion	5.03	1.15	1–7 (totally disagree–totally agree)	3	.69[b]
Ageeableness	5.44	.95	1–7 (totally disagree–totally agree)	3	.41[b]
Conscientiousness	5.78	.94	1–7 (totally disagree–totally agree)	3	.59[b]
Emoional Stability	4.17	1.26	1–7 (totally disagree–totally agree)	3	.62[b]
Openness	4.83	1.17	1–7 (totally disagree–totally agree)	3	.56[b]
Numeracy[a]	280.48	49.53	76–446 points		.93[c]
Literacy[a]	277.55	45.42	113–406 points		.93[c]
Age	43.20	13.87	19–67 years	1	
Income	2610.99	2759.98	EUR 0–86.666.67	1	
Health	3.78	.96	1–5 (very good–bad)	1	
Life satisfaction	7.40	1.27	1–10 (totally unsatisfied–totally satisfied)	12	.81[b]

[a] Based on first plausible value

[b] Cronbach's alpha

[c] Estimated as the square root of the correlation between literacy and numeracy

Table 5 Descriptive Statistics for categorical variables

Variables	Categories	Frequencies (%)
Gender	Women	51
	Men	49
Education	ISCED1	5
	ISCED2	10
	ISCED 3	43
	ISCED 4	8
	ISCED 5	33
	ISCED 6	1
Migration	German	90
	Other	10
Employment status (full-time)	No full-time	51
	Full-time	49
Continuing education	No	47
	Yes	53

Table 6 Relationships between personality, literacy, and important life outcomes

Model	Educational attainment (ISCED)[a]			Employment status (full-time)[a,b]			Continuing education[a,b]		
	I	II	III	I	II	III	I	II	III
Extraversion (linear)	−.09***		−.04*	.01		.02	−.02		−.01
Agreeableness (linear)	−.04*		−.03	−.12***		−.12***	−.05*		−.05
Conscientiousness (linear)	−.03		.01	.17***		.17***	.03		.04
Emotional stability (linear)	.12***		.06***	.12***		.12***	.06*		.05*
Openness (linear)	.14***		.10***	−.02		−.02	.01		.01
Extraversion (quadratic)	−.02		−.02	.05		.05	−.04		−.05*
Agreeableness (quadratic)	−.04*		−.03	−.02		−.01	.02		.02
Conscientiousness (quadratic)	−.07***		−.03	.01		.01	−.03		−.02
Emotional stability (quadratic)	−.03		−.02	−.01		−.01	−.02		−.02
Openness (quadratic)	−.01		.00	−.01		−.01	.01		.02
Literacy		.50***	.48***		.09**	.10***		.20***	.20***
Age	.16***	.25***	.24***	−.15***	−.11***	−.13***	−.07**	−.02	−.03
Gender (women)	−.01	−.03	−.02	−.53***	−.53***	−.53***	−.03	−.05*	−.04
Education	–	–	–	.27***	.23***	.23***	.34***	.26***	.25***
Migration (migrant)	−.09***	.01	.01	−.03	−.02	−.01	−.08***	−.05*	−.05*
N	3174	3174	3174	2868	2868	2868	2800	2800	2800
R^2	.08	.27	.28	.31[c]	.29[c]	.31[c]	.13[c]	.15[c]	.15[c]

Values are standardized regression coefficients, * p < .05, ** p < .01, *** p < .001

[a] Only respondents who have completed their education (paus1_14)

[b] Only respondents who are not retired

[c] Pseudo R^2. The regression coefficients for literacy maximally changed by $\Delta = .04$

Table 7 Relationships between personality, literacy, and important life outcomes

Model	Income (log)[a,b]			Health			Life satisfaction		
	I	II	III	I	II	III	I	II	III
Extraversion (linear)	.03		.04	.02		.02	.01		.02
Agreeableness (linear)	−.02		−.01	.05**		.05**	.09***		.09***
Conscientiousness (linear)	−.02		.01	.04*		.04*	.13***		.14***
Emotional stability (linear)	.01		.00	.21***		.20***	.32***		.31***
Openness (linear)	−.12***		−.12***	−.01		−.01	.00		.00
Extraversion (quadratic)	−.02		−.03	.00		.00	−.01		−.01
Agreeableness (quadratic)	.05*		.06*	.00		.00	.02		.02
Conscientiousness (quadratic)	−.04		−.03	−.02		−.02	.00		.01
Emotional stability (quadratic)	−.02		−.02	−.04**		−.04*	−.02		−.02
Openness (quadratic)	−.07**		−.07**	−.02		−.02	−.03		−.03
Literacy		.14***	.14***		.10***	.09***		.12***	.11***
Age	.22***	.26***	.26***	−.34***	−.30***	−.31***	−.12***	−.06**	−.08***
Gender (women)	−.13***	−.14***	−.13***	.00	−.03	.00	.03*	−.01	.03*
Education	.28***	.20***	.21***	.14***	.12***	.10***	.11***	.09***	.06***
Migration (migrant)	−.01	.00	.01	−.02	−.01	.00	−.04**	−.04*	−.02
N	1626	1626	1626	3716	3716	3716	3717	3717	3717
R^2	.19	.18	.20	.16	.11	.16	.17	.04	.17

Values are standardized regression coefficients, * p < .05, ** p < .01, *** p < .001

[a] Only respondents who are not retired

[b] Only respondents in full-time employment

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