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Openness to Experience, Fluid Intelligence, and Crystallized Intelligence in Middle-Aged and Old Adults

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Abstract

The present study examined the associations between three aspects of Openness to Experience (Intellectual Interests, Aesthetic Interests, and Unconventionality) and two broad cognitive domains (fluid and crystallized intelligence) in a large middle-aged and old adult sample. Results show that both the measurements of Openness and intelligence were strongly invariant across age groups. Older adults were less intellectually interested and described themselves as more conventional. In both age groups, Aesthetic Interests exerted a small negative effect on fluid and crystallized intelligence while Unconventionality had a positive effect. Moreover, the positive effect of Intellectual Interests was stronger in the older age group. These findings indicate that Openness-intelligence relations depend on the aspect of Openness and on the cognitive domain examined.

Keywords: Openness to Experience; Fluid Intelligence; Crystallized Intelligence; Measurement Invariance; Age Differences; Commonality Analysis
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The present study investigated the relations between two broad domains of psychological research, namely personality and intelligence. Personality traits and intellectual abilities have traditionally been seen as largely distinct domains. More recently, however, there is a renewed scientific interest concerning the relation between personality and intelligence as reflected by a growing number of research studies (Ackerman & Heggestad, 1997; Chamorro-Premuzic & Furnham, 2004). One particular personality trait that has been suggested to lie at the core of a possible personality-intelligence link is Openness to Experience, which reflects a person’s willingness to explore, consider, and tolerate new experiences, ideas, and feelings. On the intelligence side, fluid and crystallized intelligence have often been examined in conjunction with personality. Fluid intelligence denotes the ability to acquire new knowledge, whereas crystallized intelligence captures the amount of already acquired knowledge (cf. Horn & Hofer, 1992). It has been found that Openness to Experience typically relates more strongly to crystallized intelligence, with correlations being around .35 (e.g., Goff & Ackermann, 1992), than with fluid intelligence, where correlations are usually around .15 (e.g., Chamorro-Premuzic, Moutafi, & Furnham, 2005).

Research on the Openness-intelligence relation has almost exclusively been conducted in samples of young adults (but see Baker & Bichsel, 2006). From a developmental perspective, however, one may wonder whether the strength of association between openness and intelligence remains unaltered across different age groups or whether it changes systematically with age. As we will lay out in the following, based on the investment hypothesis (Cattell, 1963) there are reasons to expect that the link between openness and intellectual functioning, especially crystallized intelligence, becomes stronger in older adults (cf. Ackerman, 1997; Chamorro-
Premuzic & Furnham, 2004; Hofer & Sliwinski, 2001; McCrae, 1987). In order to examine this issue empirically, we first investigated whether the measures of openness and intelligence, both being conceptualized as latent variables, were invariant across two adult age groups (middle-aged adults and old adults) sampled in the present study. Openness to Experience was differentiated into three item clusters, namely, Aesthetic Interests, Intellectual Interests, and Unconventionality (cf. Chapman, 2007; Saucier, 1998). Second, after having established strong measurement invariance, we examined the covariances among the latent openness and intelligence variables and tested whether they were of equal size in the two age groups. Finally, we conducted a commonality analysis in order to decompose the unique and common portions of the three Openness item clusters, fluid intelligence, and crystallized intelligence.

**Openness to Experience**

Openness to Experience reflects one of the five fundamental dimensions of personality (McCrae, 1993-1994). Broadly, it refers to individual differences in the proneness to be original, complex, creative, and open to new ideas (cf. John & Srivastava, 1999). As such, it includes a motivational component, which is based on a general interest in novelty, complexity, and tolerance of ambiguity. In addition, it contains a cognitive component, which refers to the manner in which information is processed and organized. According to Costa and McCrae (1995), Openness to Experience is composed of six facets: Fantasy (a tendency toward a vivid imagination and fantasy life), Aesthetics (a tendency to appreciate art, music, and poetry), Feelings (being receptive to inner emotional states and valuing emotional experience), Actions (an inclination to try new activities, visit new places, and try new foods), Ideas (a tendency to be intellectually curious and open to new ideas and an active pursuit of intellectual interests for their own sake), and Values (a readiness to re-examine traditional social, religious, and political values). Although the conceptualization of Openness and, hence, its label have been the subject
of some scientific debate (cf. McCrae & Costa, 1997), in the present study we use the term “Openness to Experience” throughout, because we administered the scale with the same name from the NEO-FFI (Costa & McCrae, 1992b).

A common assumption is that Openness to Experience as a personality trait refers to an enduring pattern of thoughts, feelings, and behaviors. However, there is both cross-sectional and longitudinal evidence for small, but systematic age changes or age-related differences in personality traits at various ages (e.g., Allemand, Zimprich, & Hendriks, 2008; Allemand, Zimprich, & Hertzog, 2007; Allemand, Zimprich, & Martin, 2008; Roberts, Robins, Caspi, & Trzesniewski, 2003; Roberts, Walton, & Viechtbauer, 2006; Terracciano, McCrae, Brant, & Costa, 2005). With respect to Openness to Experience, Roberts et al. (2003) concluded that cross-sectional studies show a slight decrease with age across adulthood (e.g., Costa et al., 1986; McCrae et al., 1999). For example, in a large sample of Internet users aged 21 to 60 years, Openness to Experience showed a small decline with age (Srivastava et al., 2003). Srivastava et al.’s findings were similar to those reported in McCrae et al.’s (1999) multi-national studies with a total sample size of over 12,000 adults, where, across cultures, the median correlations of age with Openness to Experience was –0.08. Recently, in a sample of Medicare patients aged 65 to 100 years, Weiss et al. (2005) reported a similar negative correlation between age and Openness to Experience ($r = –.07$). Longitudinally, Roberts et al. (2006) demonstrated that, on average, people show increases in Openness to Experience in the college years. During adulthood, Openness to Experience remains largely unchanged, but declines slightly after the age of 60. A similar picture emerged from studies focusing on adulthood and old age. For example, across a 6-year longitudinal time span Small, Hertzog, Hultsch, and Dixon (2003) found a moderate decline in Openness for adults initially aged 55 to 85 years. Likewise, Schaie, Willis, and Caskie (2004) reported a modest longitudinal increase of Openness to Experience until age 46, a plateau until
the late sixties, and a modest decline thereafter. Terracciano et al. (2005) offered a more
differentiated picture of the developmental trajectory of Openness to Experience by examining
the six facets of Openness (cf. Costa & McCrae, 1995). Following the general trend, the facets
Openness to Values, Openness to Feelings, and Openness to Actions showed a small linear
decline from age 30 to 90. By contrast, the remaining three facets of Openness, i.e., Openness to
Aesthetics, Openness to Ideas, and Openness to Fantasy, exhibited almost no decline, on average.
These latter findings indicate that merely considering Openness as a whole might result in an
overly simplified picture of age-related changes in Openness.

*Openness to Experience and Intelligence*

A possible relation between Openness to Experience and intelligence has been
investigated in a number of studies during the last years. Typically, it was found that Openness to
Experience shows substantive correlations with measures of intelligence (e.g., Chamorro et al.,
2005; Goff & Ackerman, 1992; Moutafi, Furnham, & Crump, 2003). Specifically, in adult
samples, Openness to Experience has been shown to relate to general intelligence with
correlations ranging from about $r = .15$ (Moutafi et al., 2003) to $r = .42$ (Holland, Dollinger,
Holland, & McDonald, 1995). In a meta-analysis based on 135 studies, Ackerman and Heggestad
(1997) examined a variety of personality and intelligence measures regarding their
intercorrelations. Distinguishing between fluid and crystallized intelligence, the authors found
that Openness correlated weakly with fluid intelligence ($r = .08$), while the association with
crystallized intelligence was moderate ($r = .30$). Recently, Ashton and colleagues (2000) applied
the Multidimensional Aptitude Battery to assess fluid and crystallized intelligence and the
Personality Research Form scales to measure Openness in a sample of 508 adolescents and
adults. They reported that Openness correlated $r = .18$ with fluid intelligence and $r = .37$ with
crystallized intelligence. Thus, while a number of studies have found that Openness is a strong
predictor of crystallized intelligence but only weakly related to fluid intelligence (e.g., Bates & Shieles, 2003; Costa & McCrae, 1992a), in some studies crystallized and fluid intelligence did not differ in their relation to Openness to Experience (e.g., Austin, Deary, & Gibson, 1997; Holland et al., 1995; McCrae, 1993-1994). Notwithstanding, the typical finding appears to be that, in adult samples, Openness is weakly correlated with fluid intelligence, while correlations with crystallized intelligence being in the medium range ($r_s$ being around .35) (Ackerman & Goff, 1994; Goff & Ackerman, 1992; Rocklin, 1994).

Studies that distinguished between the facets of Openness to Experience and their relations to intelligence are scarce. Regarding general intelligence, the facet Openness to Ideas repeatedly emerged as a significant predictor (Harris, 2004; Moutafi et al., 2003). Goff and Ackerman (1992) found that Openness for Ideas explained 10% of variance in crystallized intelligence, but only 2% in fluid intelligence. By contrast, Openness for Values and Openness for Aesthetics explained 2% and 3% of variance in crystallized intelligence, respectively (cf. Ackerman & Goff, 1994). Focusing on fluid intelligence, Moutafi, Furnham and Crump (2006) showed that the two facets Openness to Ideas and Openness to Actions were positively correlated with fluid intelligence ($r_s = .20, .07$, respectively). In sum, it appears that the facet Openness to Ideas is associated with both fluid and, in particular, crystallized intelligence.

In order to account for the Openness-intelligence associations reported above, Chamorro-Premuzic and Furnham (2004) have recently argued that some personality traits may play a significant role in the process of skill acquisition in that they may influence choices to engage or invest in particular domains of knowledge. Hence, Openness to Experience might lead to engaging in intellectually beneficial activities, which, in turn, may strengthen the development of intellectual abilities, particularly crystallized intelligence. Similar arguments have been offered by Ackerman (1994, 1996), who emphasized the role of non-ability attributes in the development
of intelligence. Based on the assumption that fluid intelligence is cumulatively invested into specific domains of knowledge and, ultimately, transforms into crystallized intelligence, the intensity and direction of fluid intelligence investment over a longer period of time may be determined by motivation, interests, and personality traits, e.g., Openness to Experience (Ackerman, 1994, 1996; Ackerman & Heggestad, 1997). This rationale is inspired by Cattell’s (1963) investment hypothesis, which posits that fluid intelligence turns into crystallized intelligence by continuously being directed into specific areas of knowledge. As outlined in his triadic theory, Cattell (1987) posited that for channelling fluid intelligence, personality plays an important role, along with specific training and experience. Specifically, the variety of exposure, the time and energy spent, the reinforcement schedules in particular areas of experience, and the sentiments and motivational systems that grow up around certain activities are believed to be influenced by personality traits to a substantive extent. Openness to Experience, in turn, is descriptive of a tendency for individuals to immerse themselves in a task and to fully comprehend an area of interest (McCrae, 1996). As such, Openness to Experience might affect the direction and intensity of the investment of fluid intelligence and, therefore, lead to individual differences in the breadth and depth of the acquisition of knowledge and expertise, that is, crystallized intelligence (Ackerman & Beier, 2003).

A noteworthy feature of the approaches aiming to account for the personality-intelligence relation is that they draw on developmental processes to explain a link between Openness to Experience, fluid intelligence, and, especially, crystallized intelligence. Fluid intelligence is invested into specific domains of knowledge over time, which leads to the cumulative evolvement of crystallized intelligence. In accordance with this assumption, a number of studies have shown that fluid and crystallized intelligence follow different trajectories across the adult lifespan. While fluid intelligence tends to decrease linearly after the age of thirty, crystallized
intelligence remains stable into old age (e.g., Horn & Cattell, 1966; Horn & Hofer, 1992; Salthouse, 1991; Schaie, 2005). In keeping with a developmental view, Openness to Experience might explain some proportion of the age changes and age-related differences in fluid and crystallized intelligence. If one assumes that a person high in Openness to Experience engages to a larger extent in novel activities, this may, through a lifetime of practice, lead to higher levels of fluid and crystallized intelligence (Chamorro et al., 2005; Schaie et al., 2004). Specifically, if the process of engaging in a manifold of novel activities is cumulative across the lifespan, one might expect that the relation between Openness to Experience and fluid and crystallized intelligence would be stronger in older than in younger or middle-aged adults. As Hofer and Sliwinski (2001) have demonstrated, if two variables develop together on the individual level, this should lead to a dedifferentiation across time or, cross-sectionally, age groups. That is, if the development of Openness to Experience within the individual affects the development of fluid and crystallized intelligence, over time Openness to Experience as well as fluid and crystallized should become more strongly related because coupled intraindividual processes lead to more pronounced and stronger associated interindividual differences. Empirically, such a dedifferentiation would find expression as a cross-sectional interaction between age, Openness and intelligence.

*The Present Study*

The main goal of the present study was to more closely examine the interplay between individual differences in Openness to Experience and fluid and crystallized intelligence in two large, representative samples of middle-aged and old participants from Germany. Specifically, if the investment hypothesis should hold, we would expect the linkage between Openness to Experience and, especially, crystallized intelligence to be stronger in the older age group (Cattell, 1987; McCrae, 1987). That is, there should be an interaction of age group with the Openness-intelligence link. A related objective was to investigate the Openness-intelligence association on
the facet level rather than for Openness to Experience as a whole, which has the potential to provide new insights into the processes that govern personality-intelligence relations. Because we utilized the short form of the NEO Personality Inventory, the NEO-FFI (Costa & McCrae, 1992b), which does not contain facets, we examined whether nine items designated to measure Openness to Experience fell into three item clusters. The allocation of items to item-clusters was motivated by previous work of Saucier (1998) and Chapman (2007), who demonstrated that item clusters of Openness to Experience as found in the NEO-FFI highly corresponded to the Openness facets of the NEO-PI-R. Specifically, the item cluster Aesthetic Interests was strongly related to the facet Openness to Aesthetics ($r = .83$), Intellectual Interests mirrored Openness to Ideas ($r = .90$), and Unconventionality was highly similar to Openness to Values ($r = .75$). Note that item clusters are somewhat broader and based on fewer items than facets.

Methodologically, we built on and extended previous studies in several respects. While in most previous studies analyses have been conducted using sum or scale scores as measures of Openness to Experience (or its facets) (e.g., Ackerman & Goff, 1994; Baker & Bichsel, 2006; Chamorro-Premuzic & Furnham, 2004), we used structural equation modeling. Conducting analyses on the latent variable level required two additional methodological refinements: First, in order to make factor scores of both Openness to Experience and intelligence comparable across age groups, we investigated different degrees of measurement invariance (Zimprich, Allemand, & Hornung, 2006). As Horn and McArdle (1992) have argued, if evidence supporting a measure’s invariance is lacking, conclusions based on that measure are, at best, ambiguous and, at least, incorrect. We, thus, aimed at establishing strong measurement invariance for all constructs involved in the analyses (cf. Meredith, 1993). Eventually, we more closely examined the multivariate interplay among the three item clusters of Openness to Experience and fluid and crystallized intelligence by conducting a commonality analysis (Pedhazur, 1982).
Methods

Sample

Data come from the Interdisciplinary Study on Adult Development (ILSE; Allemand et al., 2007, 2008b), an ongoing interdisciplinary longitudinal study on the psychological, physical, and social antecedents and consequences of aging in Germany. In ILSE, participants come from two cohorts, one comprised of individuals born before World War II and the other including individuals born shortly after the war (i.e., 1930-1932 versus 1950-1952). The present study included persons who participated at first measurement occasions (T1: 1994) and had complete data records for the variables of interest, resulting in a sample size of $N = 1251$ (middle-aged: $n = 679$, old: $n = 572$). Middle-aged participants were, on average, 43.72 years old ($SD = 0.93$ years, 42-46 years), with 48.3% of the sample being female. Mean age of the old participants was 62.46 years ($SD = 0.94$ years, 60-64 years), with 48.4% of the sample being female. On a 5-point Likert-type scale ranging from 1 (poor) to 5 (very good), mean subjective health ratings were 3.73 ($SD = 0.99$) for middle-aged participants and 3.72 ($SD = 0.98$) for old-aged participants.

Years of education were, on average, 11.04 ($SD = 2.64$) for the younger age group and 10.29 ($SD = 2.85$) for the older age group ($t = 4.79$, $df = 1249$, $p < .01$). Although statistically significant, with respect to effect size ($R^2 = 1.8\%$) this difference was small.

Measures

Part of the testing protocol of ILSE was the German Revised NEO-Personality Inventory (NEO-FFI; Borkenau & Ostendorf, 1993; Costa & McCrae, 1992b), the Information, Similarities, Picture Completion, and Block Design subtests of the German Version of the WAIS-R (Tewes, 1991), and the Spatial-Ability subtest from a major German intelligence battery (LPS; Horn, 1983).

Openness to Experience.
Openness to Experience was measured using nine items of the German NEO-FFI Openness subscale (Borkenau & Ostendorf, 1993). The NEO-FFI is a 60-item instrument designed to measure the Big Five personality factors, with each personality factor being assessed by 12 items. While the full version of the NEO-Personality Inventory Revised (NEO-PI-R, cf. Costa & McCrae, 1992b) divides the five personality factors in so-called facets, these are not present in the NEO-FFI. However, as Saucier (1998) has demonstrated, ten of the twelve items of the NEO-FFI designated to measure Openness to Experience fall into three distinct, albeit related, clusters: Aesthetic Interests (a wide interest and appreciation for art and beauty), Intellectual Interests (active pursuit of intellectual interests, willingness to consider new ideas), and Unconventionality (readiness to reexamine social, political, and religious values). Recently, Chapman (2007) replicated this item cluster structure.

**Aesthetic Interests.** As manifest indicators of Aesthetic Interests the NEO-FFI Items 13 (“I am intrigued by the patterns I find in art and nature.”), 23 (“Poetry has little or no effect on me.”), and 43 (“Sometimes when I am reading poetry or looking at a work of art, I feel a chill or wave of excitement.”) were selected. Item 23 was reversed such that for all three items higher scores indicate more pronounced Aesthetic Interests. Note that all three items stem from the facet “Openness for Aesthetics” in the NEO-PI-R.

**Intellectual Interests.** As manifest indicators of Intellectual Interests the following items from the NEO-FFI were selected: Item 48 (“I have little interest in speculating on the nature of the universe or the human condition.”), Item 53 (“I have a lot of intellectual curiosity.”), and Item 58 (“I often enjoy playing with theories or abstract ideas.”). Item 48 was reversed in order to have higher scores of all three items indicating more pronounced intellectual interests. All three items belong to the facet “Openness for Ideas” in the NEO-PI-R.

**Unconventionality.** From the NEO-FFI, Item 8 (“Once I find the right way to do
something, I stick to it.”), Item 18 (“I believe letting students hear controversial speakers can only confuse or mislead them.”), and Item 38 (“I believe we should look to our religious authorities for decisions on moral issues.”) were selected as manifest indicators of Unconventionality. All three items were reversed such that higher scores reflect more pronounced unconventionality. While Items 18 and 38 stemmed from the “Openness for Values” facet of the NEO-PI-R, Item 8 is designated to reflect “Openness for Actions.” That is, for Unconventionality, items from two different facets were utilized. Observe that, in contrast to Saucier (1998), we did not include Item 3 (“I don't like to waste my time daydreaming”) into the Unconventionality cluster. Preliminary analyses had shown that it was virtually unrelated to the other items in both age groups. Hence, we decided to skip Item 3 from further analyses.

**Fluid Intelligence**

Fluid intelligence was assessed using three different manifest indicators, namely, Spatial Ability, Block Design, and Picture Completion.

**Spatial Ability.** This task required participants to count the number of surfaces (including hidden ones) in 40 different three-dimensional images of geometrical figures taken from the LPS (Horn, 1983). In total, participants were given three minutes to work on the task. Every correct answer was scored with one point. Correct responses were summed in order to form a total score of Spatial Ability (possible range: 0–40).

**Block Design.** This task, which was taken from the German version of the WAIS-R (Tewes, 1991), required participants to reproduce abstract patterns using nine colored blocks. In total, there were nine different patterns that had to be reproduced, each within a given maximum time limit. Scoring depended on both the correctness of the solution and the time needed. For every correct solution within the maximum time limit, two or four points were scored, depending on the complexity of the abstract pattern. Two or three additional points, again depending on the
complexity of the pattern, were scored if the time to reproduce the pattern correctly fell below certain time limits. The nine item scores were added to form a total score of Block Design (possible range: 0-51).

*Picture Completion.* This task, which stemmed from the German WAIS-R (Tewes, 1991), required participants to mention details that were missing on pictures of simple objects (e.g., a car with a missing wheel). In total, there were 17 pictures. For each picture participants were given 20 seconds time to mention the missing detail. Every correct response was scored with one point. Correct responses were added to form a total score of Picture Completion (possible range: 0-17).

*Crystallized Intelligence*

Crystallized intelligence was measured using three different manifest indicators, namely, Picture Completion (see above), Information, and Similarities. As McArdle and Prescott (1992) have shown, Picture Completion is best conceptualized as being a marker of both fluid intelligence—participants have to reason which logically necessary part of an object is missing—and crystallized intelligence—in order to recognize objects as familiar or common objects, knowledge is required (cf. Horn, 1985).

*Information.* This task, which was taken from the German WAIS-R (Tewes, 1991), required participants to answer a total of 24 questions from different knowledge domains (e.g., what is an ode?). Every correct response was scored with one point. All correct responses were summed up to form a total score of Information (possible range: 0-24).

*Similarities.* For this task, which stemmed from the German WAIS-R (Tewes, 1991), participants were asked to name what two concepts had in common (e.g., zoo—library). In total, there were 16 pairs of concepts. Depending on the quality of the response, correct solutions were scored with one or two points. Correct answers were added to form a total score of Similarities.
Measurement invariance (MI) as assessed by means of multiple-groups factor analysis is a question of degree, that is, a hierarchy of levels of MI can be distinguished (Meredith, 1993; Meredith & Horn, 2001; Zimprich et al., 2006). For \textit{configural invariance} to hold, the form of the model in terms of zero and nonzero parameters must be identical across groups, but the values of the nonzero parameters are allowed to differ between groups. Configural invariance implies that the factors represent the same construct across groups, but these constructs cannot necessarily be compared directly across groups due to possible inequalities of measurement. The next level of MI requires factor loadings to be equal across groups, a condition known as \textit{weak measurement invariance}. If weak measurement invariance holds, factor (co-)variances may be compared unambiguously across groups. For comparisons of factor means to be valid, \textit{strong factorial invariance} is required such that, in addition to factor loadings, the latent intercepts of the observed indicators are equal across groups. Finally, \textit{strict factorial invariance} holds if, in addition to the above conditions, the residual variances of the observed indicators are equal across groups. Strict factorial invariance implies that all of the differences in means, variances, and covariances of the observed indicators across groups arise from differences in latent variables or factors. Because the NEO-FFI Openness items were answered on a Likert-type scale, we decided to treat the data as being ordered-categorical. The extension of factor analysis of ordered-categorical variables to multiple groups raises some identification problems. Recently, however, Millsap and Yun-Tein (2004) developed a complete set of restrictions sufficient for identification of the configural invariance multiple-groups factor analysis model of ordered-categorical variables. Their approach was used in the present investigations. To parameterize the multiple groups models presented below, we used the same approach as in Allemand et al. (2007, 2008a,
that is, common factors were scaled by fixing their variances to 1 and all loadings were estimated freely. Furthermore, we chose to set the factor means to zero and estimate intercepts of all manifest indicators instead. These constraints, however, were relaxed depending on the model specified and its identification status.

All analyses were conducted using MPLUS version 3.0 and weighted least squares estimation (Muthén & Muthén, 2004). The absolute goodness-of-fit of models was evaluated using the $\chi^2$-test and the Root Mean Square Error of Approximation (RMSEA), where values equal to .06 or smaller indicate an acceptable model fit (cf. Hu & Bentler, 1999). In comparing the relative fit of nested models, we used the $\chi^2$-difference test. Due to its dependency on sample size, we supplement the $\chi^2$-difference test by the Root Deterioration per Restriction (RDR) index, which was suggested by Browne and Du Toit (1992). Briefly, the RDR reflects the average effect on the population fit of a more complex model from the additional restrictions being applied in a more simple structure. Since it is scaled like the RMSEA, values of the RDR less than .06 indicate that relative model fit between two nested models is comparable. As a measure of effect size for mean differences, we report Cohen’s $d$ (Cohen, 1988, p. 20).

**Results**

Results are presented as follows: In a first step, measurement models for Openness to Experience and fluid and crystallized intelligence are described separately. Second, several models including the latent variables of Openness to Experience and intelligence are presented. The third step involves the commonality analysis. Intercorrelations among the 9 Openness items, the manifest cognitive variables, and age are shown in Table 1.

*Openness to Experience*

Multiple-groups confirmatory factor analysis started with Model OM0, a model of three common factors (Aesthetic Interests, Intellectual Interests, and Unconventionality) with three
items per factor in both age groups. As can be seen from Table 2, Model OM0 did achieve an acceptable fit as judged by the RMSEA. Although the \( \chi^2 \)-value indicated statistically significant departures between actual associations and those predicted by Model OM0, this discrepancy is owed to the large sample size in the present study. Thus, regarding the nine Openness to Experience items and the three factors proposed, configural invariance appeared to hold across age groups. Note that this also implied that Saucier's (1998) item cluster approach of the NEO-FFI was replicated for Openness to Experience in a sample of middle-aged and old adults (cf. Chapman, 2007).

Next, for a model of weak measurement invariance (OM1), factor loadings were constrained to be equal across age groups. Although Model OM1 evinced an acceptable fit, it represented a statistically significant decrement compared to Model OM0 (see Table 2). However, as indexed by the RDR, this decrement in fit was negligible from a perspective of practical significance. In addition, RMSEA values did only increase marginally. Together, we regarded this as evidence that weak measurement invariance holds across age groups. In the older group, factor variances were considerably smaller than in the middle-aged group.

Subsequently, the thresholds of all items were constrained to be equal across groups, thus imposing strong measurement invariance in model OM2. For Model OM2, fit was acceptable (see Table 2), and albeit it had decreased significantly compared to Model OM1, from a perspective of practical significance this difference was of no importance as indexed by the RDR. Also, there was only a small change in RMSEA, implying that model fit was virtually identical. In sum, we considered this as being indicative of strong measurement invariance to hold in middle-aged and old adults. In the older group, factor means were 0.231, -0.096, and -0.684 for Aesthetic Interests, Intellectual Interests, and Unconventionality, respectively, with the first and the last being statistically significant. This implied that, compared to middle-aged adults, older
adults were more open for aesthetic experiences or interests, whereas they were less open with respect to being unconventional.

Eventually, in addition to the constraints imposed previously, residual variances of the nine manifest variables were fixed to one also in the older group. Hence, Model OM3 represented the proposition that strict measurement invariance holds across age groups. As can be seen from Table 2, the fit of Model OM3 was acceptable. Again, contrasted with the previous model, the $\chi^2$-test indicated a statistically significant decrement in fit, while both the RDR and a comparison of the RMSEA values suggested that model fit was almost equal, at least from a practical significance point of view. Consequently, strict measurement invariance could be assumed to hold across age groups.

Parameter estimates based on Model OM3 are shown in Table 3. The amount of explained variance in the nine manifest indicators ranged from 12.9% for Open8 to 52.2% for Open13 in the middle-aged with an average value of 31.7%. In the old age group, explained variance ranged from 12.7% (Open23) to 33.2% (Open 58), with an average of 23.1%. Note that the fact that in the middle-aged group the amount of explained variance in manifest indicators was larger is a direct consequence of the fact that factor loadings and residuals were equal in both age groups while factor variances were smaller in the old group. In both age groups, the amount of explained variance was larger for those items designated to measure Aesthetic Interests and Intellectual Interests than for those items designated to tap Unconventionality. Factor correlations were 0.65 (Aesthetic with Intellectual Interests), .33 (Aesthetic Interests and Unconventionality), and .21 (Intellectual Interests and Unconventionality) in the middle-aged. In the old age group, the according values were .71, .15 (non-significant), and -.17. Notably, while intellectual interests and regarding oneself as being unconventional were positively associated in middle-aged adults, in older adults a negative relationship emerged. In terms of effect sizes (Cohen's $d$), factor mean
differences were \( d = -.08 \) for Intellectual Interests, corresponding to 7\% nonoverlap of the distributions of Intellectual Interests in middle-aged and old adults or a small effect, \( d = .27 \) for Aesthetic Interests, corresponding to 20\% nonoverlap or a medium effect, and \( d = -.70 \) for Unconventionality, corresponding to 43\% nonoverlap or a large effect.

**Fluid and Crystallized Intelligence**

Following a similar procedure like that for Openness to Experience, we estimated a sequence of models to examine the degree of measurement invariance. First, a model of configural invariance of fluid (Spatial Ability, Block Design, Picture Completion) and crystallized (Picture Completion, Information, Similarities) intelligence was estimated (CF0). Observe that, in accordance with previous findings, Picture Completion was specified to be an indicator variable of both fluid and crystallized intelligence. Model CFO achieved an acceptable fit (see Table 2), albeit statistically significant discrepancies remained between the actual and the predicted covariance matrix, the RMSEA fell well below .06. Accordingly, configural invariance of a two-factor model of fluid and crystallized intelligence appears to hold across the two age groups regarding the five manifest cognitive indicators.

Next, for Model CF1, factor loadings were constrained to be equal across age groups, thus imposing weak measurement invariance. Concurrently, the constraint of factor variances being equal to one was relaxed in the old group. Model CF1 also achieved an acceptable fit, as can be seen from Table 2. Notably, the RMSEA had improved and the \( \chi^2 \)-difference was statistically not significant. Also, an RDR of .008 clearly indicated that, in fact, Model CF1 represented the data as well as Model CF0 did, while at the same time being more parsimonious. From this one might conclude that weak measurement invariance holds across groups. In the older group, the variance of the crystallized factor was 1.43, whereas the variance of the fluid factor was 0.95. That is, individual differences in fluid intelligence were slightly less pronounced in the older versus
middle-aged adults. By contrast, individual differences with respect to crystallized intelligence were considerably more pronounced in the older age group than in the middle-aged group. In the middle-aged group, the correlation between crystallized and fluid intelligence was $r = .74$, while in the old age group it equaled $r = .78$.

For Model CF2, we proceeded by constraining the latent intercepts of the five manifest variables to be equal across groups with factor means being freely estimated in the old group. According to Table 2, Model CF2 evinced an acceptable fit, which, again, represented an improvement compared to Model CF1 as judged by the RMSEA values. In line with this, both the $\chi^2$-difference and the RDR indicated that drop in model fit was negligible. Hence, one might conjecture that strong measurement invariance holds. In the old group, the factor mean of fluid intelligence was -0.55 and the factor mean of crystallized intelligence was -0.22, both being statistically significant. In terms of effect size (Cohen's $d$), the factor mean difference in fluid intelligence equaled $d = -.54$, corresponding to a medium effect. For the factor mean in crystallized intelligence, $d = -.19$, that is, a small effect. On average, thus, older adults showed a markedly lower level of fluid intelligence and a lower level of crystallized intelligence compared to middle-aged adults.

In a final model (CF3), strict measurement invariance was examined by constraining the residual variance of the manifest cognitive variables to be equal across groups. As Table 2 shows, doing so led to a model fit, which, although acceptable still in the absolute sense, represented a statistically significant and substantive decrement as compared to Model CF2. From this one might conclude that the assumption of strict measurement invariance was untenable, i.e., that residual variances of the five cognitive indicators differed across age groups. Consequently, we selected Model CF2, i.e., the model of strong measurement invariance in fluid and crystallized intelligence, as adequately describing the associations among results in Spatial Ability, Block
Design, Picture Completion, Information, and Similarities in both the middle-aged and the old age groups.

*Openness to Experience and Intelligence*

After having established strict measurement invariance for the three Openness factors (Aesthetic Interests, Intellectual Interests, and Unconventionality) and strong measurement invariance for fluid and crystallized intelligence, the prerequisite for comparing the association between Openness to Experience and intelligence was given. For a first model (OC0), models OM3a and CF2 were brought together without specifying any associations between Openness to Experience and fluid and crystallized intelligence. Hence, Model OC0 reflected the proposition that Aesthetic Interests, Intellectual Interests, and Unconventionality were completely independent of crystallized and fluid cognitive performance. Table 2 shows that fit of Model OC0 was unacceptable as judged from both the $\chi^2$-value and the RMSEA. Thus, Openness to Experience was not independent of fluid and crystallized intelligence.

Subsequently, in Model OC1, the six covariances between the three Openness factors and the two intelligence factors were freely estimated. Fit of Model OC1 was acceptable and represented a statistically significant improvement compared to Model OC0 (see Table 2). Also, the RDR value of .227 indicated that fit had increased considerably in proceeding from the more restrictive independence model OC0 to the less restrictive Model OC1. Apart from the covariance between Aesthetic Interests and fluid intelligence, all other Openness-intelligence covariances were statistically significant. Specifically, in the middle-aged group and for fluid intelligence, these covariances were 0.41 ($r = .06$) with Aesthetic Interests, 1.77 ($r = .27$) with Intellectual Interests, and 2.86 ($r = .44$) with Unconventionality. For crystallized intelligence, these covariances were 0.61 ($r = .18$), 1.71 ($r = .50$), and 2.08 ($r = .60$). By contrast, in the older age group and for fluid intelligence, covariances were 0.37 ($r = .07$) with Aesthetic Interests, 2.15 ($r = .23$) with Intellectual Interests,
= .33) with Intellectual Interests, and 2.03 (r = .41) with Unconventionality. For crystallized intelligence, the according values were 0.87 (r = .26), 2.24 (r = .54), and 1.57 (r = .49). In both age groups, thus, the associations between Openness and intelligence ranged from small effects (Aesthetic Interests and fluid intelligence) to large effects (Unconventionality and crystallized intelligence).

Next, in Model OC2, both fluid and crystallized intelligence were regressed on the three Openness factors, thus examining their multivariate associations. Note that fit of Model OC2 was the same as that of OC1, because OC2 represented a mere re-parameterization of OC1. All regression effects of fluid and crystallized intelligence on Aesthetic Interests, Intellectual Interests, and Unconventionality were statistically significant. In total, the three Openness factors explained 23% and 50% of variance in fluid and crystallized intelligence in middle-aged adults. In the older group, 29% and 50% of variance were explained. In terms of effect size, thus, the three Openness factors together exerted a large effect on fluid intelligence and a rather strong effect on crystallized intelligence in both age groups. Observe that, under this multivariate approach, Intellectual Interests and Unconventionality were positively related to fluid and crystallized intelligence, while Aesthetic Interests were negatively associated with both intelligence components in both age groups, thereby acting as a suppressor variable.

In order to statistically test for the equality of the regression of fluid and crystallized intelligence on Openness across age groups, parameters were constrained to be equal in the following model (OC3). As can be seen from Table 2, fit of Model OC3 was acceptable as judged by the RMSEA. Both the $\chi^2$-difference and the RMR, however, indexed that, compared to Model OC2, fit had decreased, implying that at least one of the regression coefficients is different in middle-aged versus old adults. Upon inspection, it appeared that the regression of both fluid and crystallized intelligence on Intellectual Interests was different across age groups, i.e., more
pronounced in older compared to middle-aged adults. In a subsequent Model OC3a, we, thus, relaxed Model OC3 by unconstraining the regression coefficients of fluid and crystallized intelligence on Intellectual Interests. Model OC3a achieved an acceptable fit and, compared to Model OC2, did no longer represent a statistically significant nor substantively relevant decrement in fit. In order to cross-check this result, we estimated an additional model, where only the two regression coefficients of fluid and crystallized intelligence on Intellectual Interests were constrained across age groups. For this model, $\chi^2 (182) = 656.21 (p < .05)$ and RMSEA = 0.0645. In comparison to Model OC2, $\Delta \chi^2 (2) = 9.39 (p < .05)$ and RMR = 0.769, indicating that model fit decreased. From this one might conclude that, multivariately, the effects of Aesthetic Interests and Unconventionality on fluid and crystallized intelligence were the same in the two age groups. By contrast, however, the effect of Intellectual Interests on both fluid and crystallized intelligence was significantly more pronounced in the older group.

**Commonality Analysis**

In order to decompose the variance accounted for in fluid and crystallized intelligence into portions attributable uniquely to Aesthetic Interests, Intellectual Interests, and Unconventionality, and to various combinations of these independent variables, a commonality analysis was conducted. Results are shown in Table 4. In line with the conventions suggested by Cohen (1988), we considered a $R^2 \approx .01$ as being indicative of a small effect and a $R^2 \approx .10$ as signaling a medium-sized effect.

The unique contribution of Aesthetic Interests in accounting for fluid intelligence is, in terms of effect size, small in both age groups. That is, Aesthetic Interests alone did hardly explain variance in intelligence, neither in middle-aged nor old adults. For crystallized intelligence and in older adults, a similar result emerged: Aesthetic Interests alone were only marginally predictive of crystallized abilities. By contrast, in middle-aged adults, the unique contribution of Aesthetic
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Interests was, in terms of effect size, small to medium. Keeping in mind that Aesthetic Interests were negatively associated with crystallized intelligence, this implies that those having more pronounced Aesthetic Interests exhibit, on average, a lower level of crystallized intelligence.

Regarding the unique contribution of Intellectual Interests in explaining fluid intelligence, in the middle-aged group a small-to-medium effect emerged from the commonality analysis, while in the old age group there was a medium effect. For crystallized intelligence, in both age groups the amount of explained variance by Intellectual Interests alone was of somewhat more than medium effect size. Taken together, thus, in both age groups those individuals being more strongly interested in intellectual issues showed, on average, higher levels in fluid and crystallized intelligence, although more so for the latter component of intellectual functioning.

With respect to the variance shared uniquely between Unconventionality and fluid intelligence, in the middle-aged group a small-to-medium effect emerged, while in the older group this effect was medium. For crystallized intelligence, the unique contribution of Unconventionality amounted to a medium-to-large effect in both age groups. Hence, as can be seen from Table 4, Unconventionality shared the largest amount of unique variance with fluid and crystallized intelligence in both middle-aged and old individuals.

Regarding the common influence of Aesthetic Interests and Intellectual Interests on fluid intelligence, in the middle-aged group a small negative effect emerged. As Jernstedt (1980) has outlined, a negative commonality indicates that the explanatory power of each one of the two predictor variables is greater when the other variable is included as well. Hence, the shared effect of Aesthetic Interests and Intellectual Interests on fluid intelligence is to interpret similar to a suppressor effect: By including both variables, although their common influence is negative, the respective unique contributions are increased. By contrast, in the older age group the common effect was small, but positive. The same pattern of results was found for crystallized intelligence,
where the common effect of Aesthetic and Intellectual Interests was small-to-medium, but negative, in the middle-aged group, and medium and positive in the old group. Thus, while in the older age group being interested in aesthetic and intellectual issues increased the explained variance in crystallized intelligence considerably, the same did not hold for middle-aged adults (see Table 4). For the variance common to Aesthetic Interests and Unconventionality, in both age groups and with respect to both fluid and crystallized intelligence, a small effect emerged, showing that the combination of more pronounced Aesthetic Interests and Unconventionality did only marginally improve the prediction of intelligence. Eventually, for the common influence of Intellectual Interests and Unconventionality on fluid intelligence there was a small-to-medium effect in both age groups. For crystallized intelligence, the shared effect was medium. Hence, the combination of Intellectual Interests and Unconventionality increased the explained variance substantially in fluid intelligence and considerably in crystallized intelligence.

Finally, the shared influence of all three Openness facets on fluid intelligence was negative in both age groups, implying that combining all predictor variables reduced—instead of increased, as one would have expected—the amount of explained variance. The same result was found for crystallized intelligence in the older group, while the combined effect was positive for the middle-aged adults. Together, these results imply that the combination of all three predictor variables only marginally improved the prediction of fluid and crystallized intelligence.

**Discussion**

The purpose of the present study was to examine the relations between Openness to Experience and fluid and crystallized intelligence in middle-aged versus old adults. Using Saucier’s (1998) alternative way of dividing NEO-FFI factors into content-based subcomponents or item clusters, we specified three common factors of Openness to Experience, i.e., Aesthetics Interests, Intellectual Interests, and Unconventionality. In line with Chapman (2007), we were
able to replicate the Openness item cluster structure in both age groups—apart from Item 3, which was virtually unrelated to the other Openness items. Compared to Saucier’s (1998) and Chapman’s (2007) analyses, we utilized factor analysis for ordered-categorical variables (Millsap & Yun-Tein, 2004), which appears more adequate given the five-point Likert scale format of the German NEO-FFI items (Borkenau & Ostendorf, 1993).

As a prerequisite for analyzing and comparing the associations between personality and intelligence in two different age groups, we examined the amount of invariance of the Openness to Experience and fluid and crystallized intelligence measures across age groups. As Meredith (1993; Meredith & Horn, 2001) and others (e.g., Horn & McArdle, 1992) have consistently argued, the issue of measurement invariance represents a necessary condition to meaningfully compare latent variable statistics across groups. To the best of our knowledge, this issue has not been addressed in previous research on personality-intelligence relations in different age groups. Using the multiple groups extension of factor analysis for ordered-categorical variables developed by Millsap and Yun-Tein (2004), we found strict measurement invariance to hold across the two age groups for the Openness model entailing the three item clusters specified in the present study. This finding indicates that factor loadings, intercepts of the manifest indicators, and residual variances for Openness to Experience were statistically indistinguishable across middle-aged and older adults, implying absence of measurement bias of the Openness item clusters resulting from age as a sample selection variable.

Pertaining to age differences in Openness factor means, older adults were more open to Aesthetic Interests (medium effect), whereas they were much less unconventional as compared to middle-aged adults (strong effect). No age differences were found regarding the factor Intellectual Interests. These mixed results are consistent with the broad picture that emerged from previous cross-sectional and longitudinal studies on personality trait development (cf. Roberts et
With respect to Openness to Experience facets, previous studies have reported higher levels of Aesthetics Interests and concurrently lower levels of Unconventionality in older adults compared to middle-aged adults. For example, Terracciano et al. (2005) recently reported longitudinal evidence for the NEO-PI-R facet Openness to Aesthetics showing almost no decline from age 30 to 90. Thus, regarding the direction of effects, our cross-sectional results closely mirror previous ones, albeit we utilized item clusters of Openness to Experience instead of facets. With respect to effect sizes, however, in our study age differences in Intellectual Interests and Unconventionality factor means were more pronounced (Borkenau & Ostendorf, 1993; Ostendorf & Angleitner, 2004). Possibly, the fact that we analyzed age differences at the latent level has contributed to mean differences being larger in our study. With respect to the measurement of fluid and crystallized intelligence, we found strong measurement invariance to hold across the two age groups for the two-factor model of fluid and crystallized intelligence. The finding of older adults showing a markedly lower mean level of fluid intelligence and a lower mean level of crystallized intelligence is consistent with previous results regarding their lifespan trajectories (Horn & Hofer, 1992; Salthouse, 1991; Schaie, 2005).

Regarding personality-intelligence relations, we were able to show that, after having established at least strong measurement invariance, in both age groups Aesthetic Interests, Intellectual Interests and Unconventionality were significantly associated with fluid and crystallized intelligence. With respect to effect size the associations ranged from small effects (Aesthetics Interests and fluid intelligence) to large effects (Unconventionality and crystallized intelligence). Openness was more strongly related to crystallized intelligence than fluid intelligence. A closer look at the facet level of Openness to Experience revealed that the same result held at the item cluster level, where the associations of Intellectual Interests and, most notably, Unconventionality with crystallized intelligence were more pronounced. Compared to
previous studies, in the present study the relations between Openness and both fluid and crystallized intelligence were generally stronger (e.g., Ackerman & Goff, 1994; Ackerman & Heggestad, 1997; Ashton et al., 2000; Bates & Shieles, 2003; Rocklin, 1994). The reasons for this finding are unclear, but one explanation might be that we modelled Openness to Experience on the latent level, thus reducing the influence of measurement error. Also, the fact that we distinguished different Openness item clusters, which show differential age relations (cf. Terracciano et al., 2005) and, apparently, differential relations to intelligence, might have contributed to this finding.

The communality analysis revealed the same basic pattern of results. Those having more pronounced aesthetic interests exhibited, on average, a lower level of crystallized intelligence. By contrast, those individuals being more strongly interested in intellectual activities showed, on average, higher levels in fluid and crystallized intelligence, although more so for the latter component. Unconventionality shared the largest amount of unique variance with fluid and crystallized intelligence. The combination of intellectual interests and Unconventionality increased the explained variance both in fluid and crystallized intelligence.

Intellectual Interests were more strongly associated with fluid and crystallized intelligence in older compared to middle-aged adults, which represents a novel finding. This finding bears direct relevance for explanatory approaches of the Openness-intelligence relation (Ackerman, 1994; Cattell, 1987; Chamorro-Premuzic & Furnham, 2004). One might assume that in old age, Intellectual Interests lead to more pronounced individual differences in intelligence than in young age, because investment differences due to Openness had more time to manifest themselves. Therefore, Intellectual Interests lead to more pronounced effects in intelligence in older persons due to their cumulative effect over a longer period of time (see Cattell, 1987; Goff, & Ackerman, 1992; Dellenbach & Zimprich, 2008). We acknowledge that a more stringent test of the
investment hypothesis would require longitudinal data. Still, the finding of Intellectual Interests being more strongly to fluid and crystallized intelligence in the older age group provides support for an extended investment hypothesis, which draws on personality playing a role in governing the amount and direction of fluid intelligence being invested.

Concerning the finding of a relatively strong association between Unconventionality and intelligence, there is no straightforward interpretation. However, if we assume that Unconventionality includes or requires a certain amount of intellectual flexibility, the finding of Unconventionality being associated with intelligence might be interpreted from the perspective of a flexibility-rigidity dimension of intellectual functioning (Schaie, 1958). Rigidity reflects a tendency of an individual not to change, a resistance to change, or a perseveration in beliefs, attitudes, or personal habits (cf. Schultz & Searleman, 2002) and, as such, appears to reflect almost the converse of unconventionality. The flexibility-rigidity dimension has long been suggested as a potent personality factor that might help to explain individual differences in cognitive decline from young adulthood into advanced old age (e.g., Schaie, Dutta, & Willis, 1991). In their meta-analysis, Schultz and Searleman (2002) concluded that rigidity decreased during the ages of 5 and 18, remained fairly stable between the ages of 18 and 60 and after age 60 increased linearly. Hence, it exhibits a lifespan trajectory that is directly opposite to Openness to Experience. Concerning the relation between rigidity and intelligence, a negative correlation emerged, implying that being more rigid is associated with lower scores in intelligence.

By contrast to Intellectual Interests and Unconventionality, Aesthetic Interests were unrelated to intelligence in terms of bivariate associations, while multivariately they were even negatively related to both intelligence components. A similar finding has been reported by Gignac, Stough, and Loukomitis (2004), who found positive associations among intelligence and the Openness facets Ideas (similar to the cluster Intellectual Interests), Values (similar to the
cluster Unconventionality), and Actions, but negative associations with Feelings, Fantasy, and Aesthetics (similar to the cluster Aesthetic Interests). Hence, it appears as if those aspects of Openness that are representative of an inner world (Fantasy), emotional states (Feelings), and a strong responsiveness to art and beauty (Aesthetics) do not enhance intellectual performance as measured by conventional tests. That is, they may reflect much more subjective aspects of Openness that do not necessarily lead to activities the outcomes of which can be measured as intelligence gains. Also, compared to the facets Ideas and Values, they do not require an intellectual or cognitive examination, but rather a more emotionally-loaded one.

The relationships among the Openness clusters and fluid/crystallized intelligence thus suggest an intriguing bipartite pattern: While individuals who are more open to matters that have to be grasped intellectually (Openness clusters Intellectual Interests and Unconventionality) show higher cognitive performance, in particular regarding crystallized intelligence, those open to matters that require a more emotionally-loaded processing (Openness cluster Aesthetic Interests) tend to have lower levels of intelligence.

Taken together, these results show the need to differentiate among facets (or item clusters) even in the NEO-FFI, because correlations among items suggested three factors, which, however, were not very strongly or even negatively related—like in the older age group. Further, age-related factor mean differences were markedly different across the different item clusters. Moreover, the associations of the three item clusters with fluid and crystallized intelligence were rather disparate. These differences would not have been detected in examining a general Openness to Experience factor only. To the contrary, focusing on Openness as whole is, in light of the results presented herein and by others (e.g., Gignac et al., 2004), expected to attenuate the relations to intelligence.
References


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*Personality Assessment, 88,* 220-234.


Imagination, Cognition and Personality, 13, 39–55.


Footnotes

1) The remaining two items from the NEO-FFI Openness scale (Items 28 and 33, “I often try new and foreign foods,” “I seldom notice the moods or feelings that different environments produce”) fell into two distinct, single-item clusters, indicating that they tap different aspects of Openness to Experience. As a consequence Saucier (1998) did not include them into further analyses—nor did we.
Table 1: Sample Correlations of Openness Items and Cognitive Variables

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Note. Below main diagonal are the correlations in the middle-aged group (n = 679), above main diagonal are the correlations in the old group (n = 572). Correlations among Openness Items are polychoric correlations.

<sup>a</sup> Reverse-keyed Item.

<sup>b</sup> Subtest from the WAIS-R (Tewes, 1991).

<sup>c</sup> Subtest from the LPS (Horn, 1983).
Table 2: Summary of Model Fitting Procedure

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<td></td>
<td></td>
</tr>
<tr>
<td>CF0 (Configural Invariance)</td>
<td>18.95*</td>
<td>6</td>
<td></td>
<td></td>
<td>.0588</td>
<td></td>
</tr>
<tr>
<td>CF1 (Weak Invariance)</td>
<td>23.10*</td>
<td>10</td>
<td>4.15</td>
<td>4</td>
<td>.0458</td>
<td>.0077</td>
</tr>
<tr>
<td>CF2 (Strong Invariance)</td>
<td>29.59*</td>
<td>13</td>
<td>6.49</td>
<td>3</td>
<td>.0452</td>
<td>.0431</td>
</tr>
<tr>
<td>CF3 (Strict Invariance)</td>
<td>73.57*</td>
<td>18</td>
<td>43.98*</td>
<td>5</td>
<td>.0703</td>
<td>.1120</td>
</tr>
<tr>
<td><strong>Combined Models</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC0 (Independence)</td>
<td>1039.14*</td>
<td>192</td>
<td></td>
<td></td>
<td>.0840</td>
<td>--</td>
</tr>
<tr>
<td>OC1, OC2</td>
<td>646.82*</td>
<td>180</td>
<td>392.32*</td>
<td>12</td>
<td>.0644</td>
<td>.2250</td>
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<tr>
<td>OC3 (bs constrained)</td>
<td>674.66*</td>
<td>186</td>
<td>27.84*</td>
<td>6</td>
<td>.0648</td>
<td>.0763</td>
</tr>
<tr>
<td>OC3a</td>
<td>655.88*</td>
<td>184</td>
<td>9.06*</td>
<td>4</td>
<td>.0640</td>
<td>.0449</td>
</tr>
</tbody>
</table>

* $p < .05$

*Note.* df = Degrees of Freedom; RMSEA = Root Mean Square Error of Approximation; RDR = Root Deterioration per Restriction.

* Represents the difference to Model OC1.
Table 3: Parameter Estimates (based on Model OM3)

<table>
<thead>
<tr>
<th>Standardized Loadings</th>
<th>Intellectual Interests</th>
<th>Aesthetic Interests</th>
<th>Unconventionality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle-Aged</td>
<td>Old</td>
<td>Middle-Aged</td>
</tr>
<tr>
<td>1. Open13</td>
<td></td>
<td>.69</td>
<td></td>
</tr>
<tr>
<td>2. Open23</td>
<td>.47</td>
<td>.36</td>
<td></td>
</tr>
<tr>
<td>3. Open43</td>
<td>.63</td>
<td>.51</td>
<td></td>
</tr>
<tr>
<td>4. Open48</td>
<td>.61</td>
<td>.57</td>
<td></td>
</tr>
<tr>
<td>5. Open53</td>
<td>.54</td>
<td>.50</td>
<td></td>
</tr>
<tr>
<td>6. Open58</td>
<td>.62</td>
<td>.58</td>
<td></td>
</tr>
<tr>
<td>7. Open8</td>
<td></td>
<td>.57</td>
<td></td>
</tr>
<tr>
<td>8. Open18</td>
<td>.46</td>
<td>.38</td>
<td></td>
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<tr>
<td>9. Open38</td>
<td>.42</td>
<td>.34</td>
<td></td>
</tr>
</tbody>
</table>

| Factor Means          | 0†        | −0.08 | 0†        | 0.24 | 0†        | −0.63 |
| Factor Variances      | 1†        | 0.79  | 1†        | 0.53 | 1†        | 0.63  |
| Factor Correlations   |           |       |           |     |           |       |

Intellectual Interests
Aesthetic Interests
Unconventionality

Note. Parameters that are not statistically significant at $p < .05$ are in Italics. $^a$ Represents reversed-keyed items; $†$ denotes a fixed parameter. Middle-Aged Adults: $n = 679$, Old Adults: $n = 572$. 

Middle-Aged Interests
Aesthetic Interests
Unconventionality
<table>
<thead>
<tr>
<th></th>
<th>Fluid Intelligence</th>
<th>Crystallized Intelligence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle-Aged</td>
<td>Old</td>
</tr>
<tr>
<td>Unique to Aesthetic Interests</td>
<td>0.018</td>
<td>0.014</td>
</tr>
<tr>
<td>Unique to Intellectual Interests</td>
<td>0.064</td>
<td>0.099</td>
</tr>
<tr>
<td>Unique to Unconventionality</td>
<td>0.126</td>
<td>0.105</td>
</tr>
<tr>
<td>Common to AI and II</td>
<td>−0.040</td>
<td>0.018</td>
</tr>
<tr>
<td>Common to AI and UN</td>
<td>0.011</td>
<td>0.038</td>
</tr>
<tr>
<td>Common to II and UN</td>
<td>0.058</td>
<td>0.082</td>
</tr>
<tr>
<td>Common to AI, II, and UN</td>
<td>−0.004</td>
<td>−0.062</td>
</tr>
<tr>
<td>Total $R^2$</td>
<td>0.233</td>
<td>0.294</td>
</tr>
</tbody>
</table>

Note. AI = Aesthetic Interests, II = Intellectual Interests, UN = Unconventionality. Middle-Aged Adults: $n = 679$. Old Adults: $n = 572$. Commonality estimates are based on Model OC2.