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Cognitive Abilities and Personality Traits in Old Age across Four Years: More Stability than Change

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Abstract

The current study (*N* = 236) examined stability and change of six cognitive abilities and three personality traits in old age (*M* = 74.12 years, *SD* = 4.40) over four years. Furthermore, we investigated whether levels of one domain were related to the other domain (and vice versa) four years later. The results showed a mean–level decline for processing speed and a mean–level increase for neuroticism. Cross–lagged effects indicated that reasoning was related to openness and conscientiousness was related to verbal knowledge four years later. In general, few and weak associations between the two domains were found. The findings showed that the development of cognitive abilities and personality traits in old age is marked more by stability than by change.

Keywords: cognitive abilities; personality traits; old age; cross–lagged models; stability; change.

Cognitive Abilities and Personality Traits in Old Age across Four Years: More Stability than Change

Old age is characterized by individual changes in various life domains such as health, cognition, and social environment. As people age, they become more susceptible to individual and environmental changes and non–normative events (Baltes, Lindenberger, & Staudinger, 2006). For example, research suggests that cognitive decline is a natural part of aging. Diverse cognitive abilities tend to decline in old age, mainly those considered to represent fluid abilities such as reasoning (Singh–Manoux et al., 2012) and processing speed (Salthouse, 1996). Nevertheless, individuals differ with respect to their cognitive performance (Matthews, 2009) and show substantial interindividual variability in cognitive decline (Wilson et al., 2002). This issue leads to the question why individuals maintain, improve or deteriorate their cognitive abilities. A considerable amount of studies identified different factors which could explain individual differences in change in cognitive abilities in old age (see Daffner, 2010, for a review). Among these studies, there has been an increased interest in examining the role of personality traits in cognitive aging.

Cognitive abilities and personality traits are core domains of individual functioning. Neither cognitive abilities nor personality traits develop solely as a function of brain development; both also rely on experience (Hofer & Alwin, 2008; Roberts & Mroczek, 2008). Both domains are moderately heritable and develop across the lifespan, but compared to cognitive abilities, developmental, social, and institutional pressures on personality unfold more slowly over the lifespan (Briley & Tucker–Drob, 2017). Furthermore, they show different normative developmental trajectories over time. That is, cognitive abilities tend to increase throughout early adulthood and then begin to show declines (cf. Craik & Bialystok, 2006). In old age, certain cognitive abilities show at least a small decline with advanced age in many, but not all, healthy individuals. Furthermore, these changes can be subtle and do not need to translate into impairment of daily activities (Howieson, 2015). Regarding personality traits, most mean–level change occurs between the ages of 20 and 40 years (cf. Roberts, Walton, & Viechtbauer, 2006). However, personality traits continue to change even in old age (e.g., Allemand, Zimprich, & Martin, 2008; Kandler, Kornadt, Hagemeyer, & Neyer, 2015; Wortman, Lucas, & Donnellan, 2012), thus tending to slightly decrease in late life (e.g., Lucas & Donnellan, 2011), except for neuroticism which again tends to increase (e.g., Kandler et al., 2015).

Although there is some empirical evidence for smaller, albeit inconsistent cross–sectional associations between the two domains of individual functioning (e.g., Baker & Bichsel, 2006; Soubelet & Salthouse, 2011), less is known about the longitudinal associations between cognitive abilities and personality traits in old age (e.g., Curtis, Windsor, & Soubelet, 2015). This study thus examined stability and change of six cognitive abilities (memory, processing speed, reasoning, verbal knowledge, verbal learning, and working memory) and three personality traits (openness, neuroticism, and conscientiousness) as well as their longitudinal associations across four years in old age.

Understanding the longitudinal associations between cognitive abilities and personality traits in old age is important for the following reasons. First, it is of interest whether stabilities and changes in one domain are related to the other domain, because both domains are central concepts defining daily functioning in old age. Personality traits describe individual differences in typical cognitive and affective experiences and behaviors. Therefore, specific traits such as openness may help older adults to maintain their cognitive abilities as they age (Baker & Bichsel, 2006), but they may also serve as a source of vulnerability with regard to cognitive decline and cognitive impairment (Chapman et al., 2012; Terracciano, Stephan, Luchetti, Albanese, & Sutin, 2017). It is also reasonable to assume that cognitive abilities are a requisite condition for personality traits to remain stable or to change in old age (cf. Moutafi, Furnham, & Crump, 2003). Second, knowing which personality traits or cognitive abilities have maintenance functions for the respective domains may help to strengthen these particular personality traits and cognitive abilities, respectively. For instance, Graham and Lacham (2012) found that stability in neuroticism and openness (compared to change in either direction) was related to better reasoning performance and faster reaction time. This indicates that maintaining a stable personality may be more beneficial than even socially desirable change (such as decline in neuroticism) for some variables (except for neuroticism and reaction time, for which decreases were also adaptive). Third, shedding light on the associations between cognitive abilities and personality traits can provide guidance for researchers to develop specific interventions such as personality interventions depending on cognitive characteristics or cognitive interventions for different personality types (Graham & Lachman, 2014).

1. Cognitive Abilities and Personality Traits

Previous research examined cross–sectional associations between cognitive abilities and personality traits but the findings are mixed (Ashton, Lee, Vernon, & Jang, 2000; Gignac, Stough, & Loukomitis, 2004; Zimprich, Allemand, & Dellenbach, 2009). Some of the inconsistency can be attributed to differences in measures of cognitive abilities and personality traits, different age groups with respect to old age, and the inclusion of different covariates, mediators and moderators across studies (cf. Luchetti, Terracciano, Stephan, & Sutin, 2016).

The most consistent personality–cognition associations were found for openness and neuroticism, whereas openness is positively related to measures of cognitive abilities, and neuroticism is negatively associated with measures of cognitive abilities (e.g., Graham & Lachman, 2012; Schaie, Willis, & Caskie, 2004). Correlation coefficients for the associations between openness and cognitive abilities ranged between .18 and .70 depending on the ability one considered (Graham & Lacham, 2014; Schaie et al., 2004; Soubelet & Salthouse, 2011; Zimprich et al., 2009). Correlation coefficients for associations between neuroticism and cognitive abilities ranged between −.16 and −.50 (cf. Curtis et al., 2015; Gow, Whiteman, Pattie, & Deary, 2005). Correlation coefficients for the associations between conscientiousness and cognitive abilities were around −.20 to .16 (Booth, Schinka, Brown, Mortimer, & Borenstein, 2006; Soubelet, 2011), alluding to inconsistent associations.

Indeed, the correlation coefficients reported in literature indicate a wide range, but on average, the associations between cognitive abilities and personality traits seem to be rather weak. A possible explanation for these weak associations may be that cognitive abilities and personality traits are assessed on different scales. That is, individuals show what they are able to perform (maximal performance) while solving cognitive tasks, and they describe their behaviors and attitudes (typical behaviors) while completing a personality questionnaire. Early work already pointed out that cognitive tests measure maximal performance in contrast to personality questionnaires which provide measures of typical performance (e.g., Ackerman, 1994; Ackerman & Heggestad, 1997).

Although recent studies reported significant, albeit weak cognition–personality associations, less is known about these associations with respect to old age, and the few existing findings show mixed results. One reason is that most previous work had cross–sectional study designs. Another reason is that the sparse longitudinal studies on the cognition–personality associations focused on unidirectional effects (i.e., personality traits only at one measurement occasion as predictors of cognitive abilities). Finally, previous work typically focused on a limited range of cognitive abilities. This study thus sought to address these limitations.

1.1 Cognitive Abilities and Openness

Individuals high in openness generally tend to be curious, creative, sensitive to aesthetics, as well as open to new ideas and experiences (Costa & McCrae, 1992). Hence, there are at least three arguments for a positive association between openness and cognitive abilities. First, openness may influence the engagement in intellectual activities, thus supporting the maintenance of cognitive functioning or even increase the levels of cognitive abilities. Second, as openness is characterized by flexible and open–minded thinking, individuals may solve problems more creatively. Third, higher levels in cognitive abilities may promote the interest in intellectual activities which results in higher openness scores. The majority of studies have reported that higher openness is linked to better cognitive performance, although the effects are generally small (cf. Curtis et al., 2015). As such, it is likely that open individuals are more prone to engage in cognitively stimulating activities such as reading newspapers, solving cross–word puzzles, or using the computer. In turn, these activities may positively affect cognitive abilities, contribute to cognitive reserve, and help to maintain cognitive functioning in old age (Chapman et al., 2012; Gow et al., 2005; Sharp, Reynolds, Pedersen, & Gatz, 2010). It may also be that cognitive abilities influence the development and maintenance of openness. For example, individuals with lower cognitive abilities may have more difficulties to cope with novel situations or challenging experiences, thus they are less open to new experiences than individuals with higher cognitive abilities (Moutafi et al., 2003).

1.2 Cognitive Abilities and Neuroticism

Individuals high in neuroticism tend to experience negative emotions such as anger, anxiety, and depression, and to be emotionally unstable (Costa & McCrae, 1992). Therefore, it is reasonable to expect negative associations between neuroticism and cognitive abilities in old age, because negative emotions may impair cognitive performance. Most studies have reported that higher neuroticism is linked to poorer cognitive performance (see Curtis et al., 2015, for a review), but several studies did not find significant cross–sectional associations between neuroticism and measures of cognitive abilities (e.g., Jelicic et al., 2003). One hypothesis is that neurotic individuals are more anxious and prone to intrusive thinking as well as to distraction that could impair their ability to focus on cognitive performance tasks, which then results in poorer cognitive functioning (Gold & Arbuckle, 1990; Graham & Lachman, 2012; Moutafi, Furnham, Paltiel, 2004). However, an alternative hypothesis would suggest that decline in cognitive ability causes older adults to become more anxious, so increasing anxiety leads to higher neuroticism scores on self–report scales (Curtis et al., 2015).

1.3 Cognitive Abilities and Conscientiousness

Individuals high in conscientiousness tend to be organized, goal–directed, persistent, self–controlled, and self–disciplined (Costa & McCrae, 1992). It is thus reasonable to expect positive associations between conscientiousness and cognitive abilities, because conscientiousness may help to maintain previous levels of cognitive abilities as individuals age. However, previous studies found mixed results for the associations between cognitive abilities and conscientiousness (see Curtis et al., 2015, for a review). Three hypotheses are currently discussed. First, conscientiousness is positively related to cognitive abilities, because it influences health behaviors, which, in turn, are protective against age–related changes in brain (Sutin et al., 2011). Second, it might be that better cognitive abilities allow individuals to maintain their levels of conscientiousness with increasing age (Mõttus, Johnson, Starr, & Deary, 2012b). Third, conscientiousness is negatively linked to cognitive abilities, whereby individuals with lower cognitive abilities become more hardworking and organized over time in order to compensate for their lower cognitive abilities (Chamorro–Premuzic & Furnham, 2004; Moutafi et al., 2004; Rammstedt, Danner, & Martin, 2016).

2. Goals of the Present Study

The present study investigated stability and change of six different cognitive abilities and three different personality traits, and their longitudinal associations across four years in old age. We had two main goals. The first goal was to examine stability and change of cognitive abilities and personality traits separately across four years. Although four years is a relatively short time period, results show that significant individual differences exist with respect to the rates and direction of changes in older adults (aged between 61 to 100 years) across relatively short time intervals between one to six years (Ghisletta & Lindenberger, 2003; Lindenberger & Reischies, 1999). In particular, we investigated whether individuals retain the same rank ordering on the variables of interest over time (rank–order stability) and whether the group of individuals increases or decreases on variables of interest over time (mean–level change). So far, very few studies investigated rank–order stability and mean–level change of cognitive abilities and personality traits in old age. Based on the sparse existing research (Hertzog, Dixon, Hultsch, & MacDonald, 2003; Kandler et al., 2015; Mõttus et al., 2012a; Wortman et al., 2012), we expected medium–sized to high rank–order stabilities and small mean–level changes for both cognitive abilities and personality traits across four years.

The second goal was to investigate the longitudinal associations between cognitive abilities and personality traits in terms of cross–lagged effects. Cross–lagged models allow to examine whether levels in one domain such as cognitive abilities are predicted by previous levels of the other domain such as personality traits (e.g., Grimm, An, McArdle, Zonderman, & Resnick, 2012). As such, we were interested in the basic (that is, levels) bidirectional longitudinal relationship between cognitive abilities and personality traits. To date, only few studies have tested whether cognitive abilities influence personality traits (e.g., Curtis et al. 2015). Furthermore, this is one of the first studies testing cross–lagged effects between cognitive abilities and personality traits. We focused on six different cognitive abilities rather than on a general cognitive ability score, tapping the full potential of our extensive cognitive assessment. The underlying idea of this modeling strategy is that levels in one cognitive domain may be related to levels of personality traits, whereas others may not (and vice versa). Given the paucity of evidence on longitudinal studies, we did not make specific predictions for the different cognitive abilities. We expected bidirectional associations between the two domains. With regard to cross–sectional literature, we expected openness and conscientiousness to be positively related to the measures of cognitive abilities, whereas neuroticism was expected to be negatively associated with cognitive abilities. In general, we expected weak associations between cognitive abilities and personality traits because they represent different domains of individual functioning, and they are also assessed on different scales using different methods. That is, cognitive tasks measure maximal performance, whereas self–report personality questionnaires measure typical behaviors.

3. Methods

3.1 Participants

Participants come from the Zurich Longitudinal Study on Cognitive Aging (Zürcher Längsschnittuntersuchung zum kognitiven Altern, ZULU; see Zimprich et al., 2008). ZULU is an ongoing longitudinal study on the structure and development of cognitive abilities in old age. It started in 2005, followed by reassessments in 2006 and 2010. Participants were recruited through three different channels. That is, (1) the registry of the city of Zurich, (2) the University of Zurich lecture series for senior citizens, and (3) by advertisements in two local newspapers, flyers or word of mouth by other participants. The ZULU sample was designed to be representative of older adults living in Switzerland (for more information, see Dellenbach & Zimprich, 2008; Mascherek & Zimprich, 2012; Zimprich et al., 2008). Because the focus of ZULU is on cognition, only three personality traits (i.e., openness, neuroticism, conscientiousness) were part of the assessment protocol to present as little burden to the participants as possible. Given that the three self–report measures of personality traits were included at the second and third measurement occasion only, this study focused on these two time points. As from now, it is referred to the two measurement occasions as T1 (2006) and T2 (2010). At T1, the sample consisted of 335 older adults.

To test for attrition effects, dropouts (n = 99) who only participated at T1 (or from whom no data on the variables of interest at T2 exist) were compared with continuers (n = 236) who participated at both measurement occasions (T1 and T2). Continuers were slightly younger (d = –.23), healthier (d = .35), more open (d = .22), more conscientious (d = .26), less neurotic (d = –.45), and slightly higher educated (d = .26) than dropouts. The groups did not significantly differ regarding their cognitive performance in verbal knowledge (d = –.03) and reading span (d = .19). Nevertheless, continuers showed slightly better performance in the cognitive tasks number comparison (d = .36), identical pictures (d = .48), letter digit substitution (d = .49), standard progressive matrices (d = .26), five verbal learning trials (d's = between .28 and .48), paired associates (d = .49), story recall (d = .29), and picture recall (d = .31). Although these differences reflect small effects (*d* < .50; Cohen, 1992), this pattern of selectivity indicates that continuers represent a positively selected subset of the original sample. The findings in this article are based explicitly on the continuer sample (53.8% male). There were no signs of cognitive impairment as assessed by the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). The mean age was 74.12 years (*SD* = 4.40, range = 66–81 years). Mean education was 13.11 years (*SD* = 3.07). Average subjective health was 3.61 (*SD* = 0.39) as measured on a Likert scale ranging from 1 (*very poor*) to 6 (*excellent*).

3.2 Measures of Cognitive Abilities

Data from ten cognitive tasks were used to measure six different cognitive abilities. The same cognitive tasks were administered at all measurement occasions. In the following section, the cognitive tasks are described briefly (see Zimprich et al., 2008, for a more detailed description and test–retest reliabilities of the cognitive tasks).

3.2.1 Memory tasks. Three tasks were used to measure memory. First, the paired associates task consisted of 12 semantically unrelated word pairs taken from the German version of the Wechsler Memory Scale–Revised (WMS–R; Härting et al., 2000) and from the Munich Verbal Memory Test (MVGT; Ilmberger, 1988). Second, the story recall task consisted of Story A of the logical memory subtest of the German version of the WMS–R (Härting et al., 2000). Third, the picture recall task comprised 12 pictures taken from the Nuremberg Age Inventory (Oswald & Fleischmann, 1999).

3.2.2 Processing speed tasks. Three tasks were used to measure processing speed. First, the number comparison task comprised 60 items (Ekstrom, French, Harman, & Dermen, 1976). Second, the identical pictures task consisted of 60 items taken from the Educational Testing

Service (ETS; Ekstrom et al., 1976). Third, the letter digit substitution task comprised 75 items (Jolles, Houx, Van Boxtel, & Ponds, 1995).

3.2.3 Reasoning task. The standard progressive matrices task consisted of 24 items (12 items from Set A and 12 items from Set B of the Standard Progressive Matrices by Raven, 1998).

3.2.4 Verbal knowledge. The spot–a–word task consisted of 37 items taken from Version A of a widely used German vocabulary test (MWT; Lehrl, 1999).

3.2.5 Verbal learning task. Five trials of a word list recall were used to assess verbal learning. This task comprised of 27 unrelated, but meaningful two– to three–syllable words taken from a manual of German word norms (Hager & Hasselhorn, 1994). To build verbal learning scores, recall performance difference scores were calculated by subtracting the score for the first trial from the scores of the other trials. Thus, four difference score variables were created (verbal learning trial 2 minus verbal learning trial 1, verbal learning trial 3 minus verbal learning trial 1, verbal learning trial 4 minus verbal learning trial 1, and verbal learning trial 5 minus verbal learning trial 1).

3.2.6 Working memory task. The reading span task was a modified version of the task used by Daneman and Carpenter (1980).

3.3 Measures of Personality Traits

Openness, neuroticism, and conscientiousness were measured using the German version of the NEO–Five–Factor Inventory (NEO–FFI; Borkenau & Ostendorf, 1993). The items were rated on a 5–point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). For openness, Cronbach's alpha was .74 (T1) and .75 (T2), whereas the omega hierarchical estimates (Zinbarg, Revelle, Yovel, & Li, 2005) were .59 (T1) and .56 (T2). For neuroticism, Cronbach's alpha was .82 (T1) and .82 (T2), whereas the omega hierarchical estimates were .64 (T1) and .63 (T2). For conscientiousness, Cronbach's alpha was .79 (T1) and .78 (T2), whereas omega hierarchical were .64 (T1) and .55 (T2). The internal consistencies of all measures at each time point ranged from acceptable to good.

3.4 Statistical Analysis

3.4.1 Power analysis. The sample size of the current longitudinal data analysis was determined using the existing ZULU data. Power calculations were conducted using the "pwr" package (Champely, 2017) in R version 1.0.143 (R Core Team, 2015), and focused on the longitudinal cross–lagged correlation coefficients. However, it is difficult to refer to prior work to inform about effect size expectations, because cross–lagged designs are rare, and different methodologies were used to assess cognitive abilities (global measure vs. specific cognitive tasks). Nevertheless, the correlation coefficients' range of .11–.32 for longitudinal associations was considered as a possible scenario for the effect size based on estimates available from the literature (Chapman et al., 2012; Gow et al., 2005; Hultsch, Hertzog, Small, & Dixon, 1999; Mõttus et al., 2012b). Our sample provides power of 39% to estimate a correlation coefficient of .11 at the 5% significance level, and a sample size of 645 participants would be needed to achieve 80% power for this value. If true correlation coefficients are .32, the power estimate would be 99%. Based on the given sample size, our cross–lagged longitudinal models were able to detect effects that are >.18 (N = 236, significance level = 0.05, power = 80%).

3.4.2 Longitudinal measurement models. Longitudinal structural equation modeling (SEM; McArdle & Nesselroade, 2014) was used to investigate the research goals. First, longitudinal measurement models were established for the six cognitive abilities and the three personality traits separately. Because reasoning, verbal knowledge, and working memory were only measured with a single cognitive test, they were estimated using manifest models (i.e., test scores). The remaining cognitive abilities were estimated as latent constructs consisted of multiple indicators (i.e., cognitive tests or questionnaire items) at T1 and T2. For each latent personality trait, parcels were created to form three manifest indicators following the item–to–construct balance technique (Little, Cunningham, Shahar, & Widaman, 2002). Correlated residual variances were allowed for the matching parcels at T1 and T2 (Marsh & Hau, 1996).

3.4.3 Longitudinal measurement invariance. First, longitudinal measurement invariance (MI) of the latent measures of cognitive abilities and personality traits was established, ensuring that these constructs are comparable over time (Meredith & Horn, 2001). It seems particularly important to establish MI in old age, because old age is a phase that is particularly susceptible to individual and environmental changes and non–normative events (Baltes et al., 2006). It may be that older individuals tend to change their internal standards of perceptions due to the accompanying changes that aging brings with it. Insufficient consideration of MI may impair the interpretation of the study results (e.g., Mõttus, Johnson, & Deary, 2012a). Following the recommendation by Little (2013), strong MI[1] was established. Confirmatory factor models were fitted with increasingly restrictions on the following parameter over time: factor loadings, intercepts, and residual variances (Meredith & Horn, 2001). First, an unconstrained measurement model of configural invariance (M1) was tested. The M1 model specifies the relationship between manifest indicators and the latent constructs. Second, a model of weak MI (M2) was tested. Hence, factor loadings were set equally over time, whereas factor variances were freely estimated at T2. Third, a model of strong MI (M3) was tested. In addition to M2, indicator intercepts were set equally over time. The factor means were freely estimated over time.

[1] Strict MI was not tested as our goal was to establish strong MI that allows for meaningfully comparisons of means, covariances, and variances over time (cf. Little, 2013).

3.4.4 Cross–lagged models. To examine the longitudinal associations between cognitive abilities and personality traits, we ran 18 bivariate autoregressive and cross–lagged regression models separately for each pair of cognitive ability and personality trait (cf. McArdle, 2009). These models allow for the simultaneous examination of the reciprocal associations between two variables (i.e., cognitive abilities and personality traits). Overall, cross–lagged models allow estimations of initial correlations, change correlations (or more precisely, correlations between residuals), the cross–lagged paths relating to cognitive abilities' levels by previous levels of personality traits, and cross–lagged paths relating to personality traits' levels by previous levels of cognitive abilities. All cognitive and personality scores were converted into *z* scores (e.g., Schaie et al., 2004; Soubelet & Salthouse, 2010, 2011) to facilitate the comparison between different cognitive data types and personality scales.

In the models examining rank–order stability, mean–level change and cross–lagged effects, we controlled for potential effects of education and age (see Curtis et al., 2015, for a review of control factors considered in the field). All SEM models were estimated using the maximum likelihood estimator. We fitted all models using Mplus 7 (Muthén & Muthén, 1998–2015). To evaluate goodness of fit of the models, the chi–square (χ^2), comparative fit index (CFI), and root mean square error of approximation (RMSEA) as well as its 90% confidence intervals (CI) were examined. CFI values above .97 and RMSEA values below .06 are considered to reflect a good fit, whereas CFI values above .95 and RMSEA values below .08 are acceptable (Browne & Cudeck, 1993; Hu & Bentler, 1998). Nested chi–square ($\Delta\chi^2$) tests were used to perform model comparisons. In addition to *p*–values, we also provide 95% CIs when reporting the cross–lagged effects. CIs contain information about the size of an effect and its precision, thus being more informative than *p*–values alone (Cohen, 1994). The data, input and output files of the present study are available upon request.

4. Results

4.1 Longitudinal Measurement Invariance

Correlations and descriptive statistics for the variables of interest are displayed in Table 1. To establish MI of the measurement models, the least restrictive model (M1: Configural invariance) was fitted for each model separately. As shown in Table 2, these models achieved acceptable fits as judged by the CFI and RMSEA. Second, factor loadings were constrained to be equal over time (M2: Weak invariance). These more restrictive models achieved acceptable fits too. Furthermore, they did not significantly differ from M1. In M3 (Strong invariance), in addition to equal factor loadings over time, the intercepts of the manifest indicators were constrained to be equal across measurement occasions. In turn, the models achieved acceptable fits and did not significantly differ from M2. This implies that strong factorial invariance holds in this sample and thus adequately captured the data. Taken together, the results indicate that factor loadings and indicator intercepts of cognitive abilities and personality traits remained invariant across time.

4.2 Rank–Order Stability and Mean–Level Change

Based on the models of strong MI (M3) we found significant rank–order stability in cognitive abilities and personality traits over the 4–year time period (Table 3). The mean rank–order stability index across cognitive abilities using the *r*–to–*z* approach was $r = .76$ and $r = .83$ across personality traits, respectively. In general, longitudinal correlations revealed relatively high levels of rank–order stability.

Based on the models of strong MI (M3), models with freely estimated factor means over time were compared with models in which the factor means were constrained to be equal across the two measurement occasions. Compared to M3 (Table 2), the models of equal means over time in processing speed and neuroticism showed a significant loss of fit, $\Delta\chi^2(1) = 16.81$, $p < .001$ (processing speed), and $\Delta\chi^2(1) = 7.04$, $p < .01$ (neuroticism). In other words, processing speed tended to decrease over time, whereas neuroticism tended to increase over time. All other models did not lead to a statistically significant decrease in model fit, indicating that these variables did not change over time. Table 3 displays the mean–level changes, whereas the first measurement occasion was used as a reference with a factor means of zero, that is, factor means at the second measurement occasion reflect deviations from the reference.

4.3 Cross–Lagged Effects

Cross–lagged models allow estimations of whether levels in one domain are related to previous levels of the other domain and vice versa controlled for initial correlations between the variables and their rank–order stability (Grimm et al., 2012). Table 4 shows the initial and change correlations (i.e., residual correlations) of the cross–lagged models. The initial correlations between cognitive abilities and personality traits indicate only few significant associations. Correlations between the T2 scores reflect the associations between levels in cognitive abilities and levels in personality traits when their initial associations as well as their cross–lagged associations are controlled. The general picture suggests that few change correlations (i.e., correlations between residuals) were found, namely only for openness and processing speed, neuroticism and verbal learning as well as conscientiousness and processing speed.

4.3.1 Effects of cognitive abilities on personality traits. We tested 18 cross–lagged effects of cognitive abilities on personality traits, whereof 1.8% were significant. As displayed in Table 5, higher (lower) levels of reasoning were related to higher (lower) levels in openness four years later ($\beta = 0.116$, $p = .038$, 95% CI [0.02, 0.21]). The effect size was small. No effects of cognitive abilities on neuroticism and conscientiousness were found.

4.3.2 Effects of personality traits on cognitive abilities. We tested 18 cross–lagged effects of personality traits on cognitive abilities, whereof again one effect was significant. Table 5 shows the cross–lagged personality traits' effects. The level of conscientiousness was significantly related to the level of verbal knowledge after four years, again with a small effect size ($\beta = -0.108$, $p = .037$, 95% CI [–0.19, –0.02]) All other effects were not significant.

5. Discussion

This study examined cognitive abilities and personality traits and their longitudinal associations in old age over four years. Based on the models of strong MI, we found relatively high rank–order stabilities and stable mean–levels for both core domains. Only few initial and change correlations between cognitive abilities and personality traits were significant. Our results suggest cross–lagged links between (1) reasoning and openness as well as (2) conscientiousness and verbal knowledge, whereas both effect sizes are relatively small. These primary and other findings are discussed in more detail below.

5.1 Equivalent Measurement Properties over Time in Old Age

From a psychometric perspective, the measurement of change requires that the cognitive tasks and the personality questionnaire measure the same construct (i.e., cognitive abilities and personality traits) across time. Although this sounds simple, the relationships between tasks or questionnaire items and their underlying constructs may be complex. These associations are typically characterized by a measurement model that needs not to stay constant across time (e.g., when participants reprioritize or reconceptualize the perceived meanings of test items across time). In our study, we established strong MI, a methodological prerequisite that is not often explicitly tested in samples beyond age 70 years, but especially important in old age (cf. Môttus et al., 2012a), as aging is characterized by manifold changes in different modalities such as cognition, health, and social environment. Strong MI warranted unbiasedness of the latent cognitive abilities and personality traits across measurement occasions. Consequently, the longitudinal comparisons of factor means were deemed to be interpretable as quantitative shifts in invariant measures.

5.2 More Stability than Change in Personality in Old Age

Based on strong MI, cognitive abilities and personality traits show relatively high levels of stability across four years in terms of rank–order correlations and factor means. The rank–order stabilities are in line with the few existing longitudinal stability coefficients reported in previous studies (e.g., Allemand, Zimprich, & Martin, 2008; Hertzog et al., 2003; Mõttus et al., 2012a; Roberts & DelVecchio, 2000). Concerning cognitive abilities, it seems that high rank–order correlations in old age support the model of “preserved differentiation” that predict stability of performance differences (Salthouse, 2006). Thus, individuals with higher and lower cognitive reserve differ in their levels of cognitive performance, but their rates of decline in performance are comparable. A possible factor that may contribute to high personality rank–order stability in old age is identity structure (Roberts & DelVecchio, 2000). In addition, personality traits would not describe what they expected to describe (enduring individual characteristics) without high rank–order stability (Mõttus et al., 2012a). Taken together, individuals generally retained their relative positions on cognitive abilities and personality traits.

But although stability coefficients were relatively high, this does not imply that there are no reliable individual differences in change of cognitive abilities and personality traits.

On the mean–level, processing speed tended to decrease over time, whereas neuroticism tended to increase. The first finding is largely consistent with previous research on cognitive abilities showing a decrease in processing speed in old age (cf. Salthouse & Ferrer–Caja, 2003). The stable mean–levels of the remaining cognitive abilities may be referred to the fact that the investigated sample was relatively healthy and well–educated, and the time interval was rather short. The increase in neuroticism may be surprising in the first instance, because some studies show that neuroticism tends to decrease with age (e.g., Allemand et al., 2008; Roberts et al., 2006). Nevertheless, it should be noted that participants of these studies were between the ages of 50–64 years. Therefore, it may be that neuroticism decreases in early old age, but then increases in later old age. Recent findings suggest that an increase in neuroticism in old age (cf. Wagner, Ram, Smith, & Gerstorf, 2016) may reflect an aging effect (Kandler et al., 2015). In other words, older individuals have to be more cautious of health–risks and dangers of everyday life (i.e., increasing neuroticism) when their cognitive, physical, and social functionality declines to maintain a comparable level of emotion regulation and well–being (Kandler et al., 2015).

Taken together, the results of this study indicate relatively stable mean levels for almost all cognitive abilities and personality traits in a sample of older adults aged between 66–81 years across a 4–year time period. It may be that there are no substantial changes in the beginning of the seventh decade, but that there may be more pronounced changes later in life, for example within the eighth or ninth decade (Mõttus et al., 2012a). The present study confirms the few existing findings and adds additional evidence suggesting relative high stability in healthy old age, even though aging is typically characterized by manifold individual changes in various life domains.

5.3 Effects of Cognitive Abilities on Personality Traits in Old Age

Considering cognitive abilities as a potential predictor of personality traits in old age has only been addressed by a few studies while previous research tended to focus on personality traits predicting levels of cognitive abilities (e.g., Curtis et al. 2015; Wettstein, Kuźma, Wahl, & Heyl, 2016). Hence, cross–lagged findings of cognitive abilities on personality traits are informative per se as they extend our knowledge of cognitive abilities predicting personality traits. In the present study, reasoning was the only cognitive ability that was significantly related to openness. As stated earlier, we did not form specific hypotheses for the different cognitive abilities, but rather explore the research topic to form the basis for more conclusive research. When it comes to different cognitive abilities (vs. general cognitive ability), it is important to distinguish between two broad categories at first. Namely, it should be differentiated between *fluid* and *crystallized* cognitive abilities in order to understand cognition–personality relations (Moutafi et al., 2003). Fluid ability involves quick thinking, reasoning, seeing relationships between ideas, approaching new problems, whereas crystallized ability is the accumulation of information of facts, figures, skills and knowledge over time (Brody, 1992). This distinction seems relevant for the interpretation of our findings. Indeed, it has been suggested that the relationship between openness and fluid abilities is different than the association with crystallized abilities (Moutafi et al., 2003; 2004). That is, individuals with lower fluid abilities (e.g., reasoning) may show more difficulties to handle novel experiences which, in turn, discourages openness. On the other hand, high openness may lead individuals to expand their crystallized abilities (e.g., verbal knowledge). This difference thus refers to the causal direction and means that openness might be influenced by fluid abilities, whereas openness might influence crystallized abilities. In other words, cross–lagged effects of cognitive abilities on openness could be expected for fluid, but not necessarily for crystallized abilities. This is in line with our results as higher (lower) levels of reasoning were related to higher (lower) levels of openness, but there was no relation between verbal knowledge and openness.

5.3.1 Reasoning and openness. A possible explanation for the reasoning–openness finding might be that individuals with lower levels of reasoning have more difficulties to draw conclusions as well as to cope with novel or challenging situations, resulting in lower levels of openness as there is no scope for development. In contrast, older adults with higher levels of reasoning benefit from this cognitive resource, seeking to stimulate and challenge themselves by the exposure to novel experiences. Consequently, they become more curious and show more intellectual interests and ideas what is related to higher levels of openness four years later. Furthermore, a positive relation between reasoning and openness was reported by a cognitive training study (Jackson, Hill, Payne, Roberts, & Stine–Morrow, 2012). In this study, older adults completed a 16–week program in inductive reasoning training and showed higher levels of openness after the training compared to the baseline assessment. Although this finding is not directly comparable as it comes from a training study, it supports evidence for a basic association between reasoning and openness (if there was no basic relationship, there would be no change) as found in our study. Even though the cross–lagged effect found in our study was relatively small, it should be noted that small effects can have serious consequences too (e.g., Ozer & Benet–Martínez, 2006). Lower reasoning capacity may shape openness in later life which in turn may influence other life outcomes (e.g., well–being). This may be even more pronounced or of higher relevance for cognitively impaired individuals. Moreover, lifespan developmental theory suggests that lifespan dynamics of an increasingly negative gain–loss ratio in cognition (Baltes & Baltes, 1990) constitute a key factor for personality development (Wagner et al., 2016). Therefore, small effects of basic relationships merit the attention to be investigated.

However, further research is required to replicate the associations between different cognitive abilities and openness. The present study did not find any cross–lagged effects of the remaining five cognitive abilities. There might be different methodological and theoretical explanations for the different abilities. For example, it may be that processing speed is unrelated to openness, because one could be curious and open to new ideas independent of how fast (or slow) one processes information four years before.

5.3.2 Null results. For neuroticism and conscientiousness, no cognitive abilities' effects were found. In contrast to our expectations, cognitive abilities were not related to neuroticism (see also Table 5). We have two explanations: First, it may be that the investigated time interval was not appropriate regarding the nature of the association between cognitive abilities and neuroticism and conscientiousness. Although the results of the present study are informative, the present study was restricted to two measurement occasions. Additionally, the time interval between these two assessments was relatively short, but it might also have been too long concerning cognition–personality relations. Time intervals that are too short or too long with regard to the nature of the variables of interest can produce data that might be overly sensitive to measurement errors and carryover effects or insensitive to variability and change (cf. Hertzog & Nesselroade, 2003). Second, it may be that cognitive abilities are related only to different facets of neuroticism or conscientiousness. For example, differences between studies for neuroticism may partly be attributable to differences in the scales (anxiety and depression vs. impulsivity and anger) used to assess neuroticism (Luchetti et al., 2016). Consequently, cognitive abilities may be differentially associated with different facets of neuroticism (Wilson, Begeny, Boyle, Schneider, & Bennett, 2011). The general picture suggests that levels of cognitive abilities are not related to levels of personality traits four years later, except for reasoning and openness.

5.4 Effects of Personality Traits on Cognitive Abilities in Old Age

Again, only one cross–lagged finding with a small effect size was detected. Namely, higher (lower) levels of conscientiousness were related to lower (higher) levels of verbal knowledge four years later. Prior studies have found negative associations between conscientiousness and different cognitive abilities too (e.g., Moutafi et al., 2004; Rammstedt et al., 2016), supporting the intelligence compensation hypothesis which assumes individuals with lower cognitive abilities become more conscientious over time to cope with their lower cognitive abilities (Moutafi et al., 2003). Our result cannot be explained by the intelligence compensation hypothesis, because the intelligence compensation hypothesis refers to the causal relationship that intelligence affects the development of conscientiousness (besides this, we did not find any effects of cognitive abilities on conscientiousness as shown in Table 5). Moutafi and colleagues (2004) postulated that there appears to be no specific theoretical explanation for more conscientious individuals to become less intelligent or for less conscientious individuals to become more intelligent. Indeed, our negative cross–lagged finding seems counterintuitive and is difficult to explain. Further research in this field would be of great help in determining the relation between conscientiousness and verbal knowledge. It might be useful to include possible third variables that may mediate or moderate this relationship.

No further cross–lagged effects of personality traits on cognitive abilities were found. It might be especially surprising that there was no significant cross–lagged effect of openness on crystallized abilities, because openness is often positively linked to them on a cross–sectional level and due to the "distinction hypothesis" mentioned earlier (cf. Moutafi et al., 2003; 2004). A possible methodological explanation for verbal knowledge might be that it was only measured with the spot–a–word task. It seems more appropriate to measure verbal knowledge using multiple tasks rather than focusing on the performance of a single task. Concerning the "distinction hypothesis", it may also be that openness is not meaningfully related with verbal knowledge in old age anymore. For instance, openness may lead individuals to expand their crystallized abilities (such as verbal knowledge) only in young and middle adulthood but not in old age. Namely, Moutafi et al. (2003) who suggested that higher openness leads to better crystallized ability investigated a sample aged between 23–64 years. Furthermore, verbal knowledge is supposed to peak at around the ages of 45–54 years. By contrast, our participants were aged between 66–81 years.

5.5 Measurement Considerations

Although we expected only small associations between cognitive abilities and personality traits, it is somewhat surprising that we found almost no associations. However, two important points should be noted. First, given that correlations are rather modest within the cognitive domains (about .3); it is difficult to expect stronger correlations between personality and any single cognitive ability. Second, it is important to keep in mind that cognitive tasks measure maximal performance, whereas personality questionnaires measure typical behaviors. It is thus reasonable to scrutinize whether or under which circumstances maximal performance is linked to typical behaviors. As such, future research might pay more attention to this distinction between maximal and typical cognitive processes and personality–related experiences and behaviors. For instance, it may be that the cognition–personality association appears stronger in individuals who realize that their cognitive abilities decline and want to "fight against it" or in individuals who want to improve their cognitive performance. This means, individuals need to be at some point where they reach some personal limit, before they change their behaviors depending on different personality traits, which not until then influence the strength of the individual cognition–personality association. Future research might explore these two domains on a more similar scale level. Today's technologies provide new opportunities to assess cognition and personality on a day–to–day typical behaviors level. For example, ambulatory assessment methods could be used to measure cognitive and personality–related behaviors in daily life. To be more specific, an intensive longitudinal study could be conducted over two weeks. During this time, older individuals would carry a smartphone provided by the study and report their daily cognitive and personality–related activities at noon and in the evening. Participants would be asked what they did as well as rate different items concerning cognitive activities (e.g., “I read the newspapers”), cognitive problems (e.g., “I forgot a date, a grocery item or my medication”), and personality–related behaviors (e.g., “I enjoyed music or art” for openness, “I felt moody” for neuroticism, “I completed everything that I planned to do” for conscientiousness, “I had an argument with somebody” for agreeableness (reverse coded), and “I talked a lot” for extraversion). Furthermore, they would rate the perception of different cognitive abilities (e.g., memory; cf. Luchetti et al., 2016), and solve brief cognitive tasks on the smartphone (e.g., working memory; cf. Riediger et al., 2014) twice a day. Consequently, cognition would be assessed not only objectively (tasks), but also subjectively like the personality–related behaviors and therefore both domains would be assessed on a similar scale level.

6. Limitations and Further Future Directions

This study has several strengths, including the longitudinal design, the wide range of assessed cognitive abilities, and the statistical techniques for examining the associations between cognitive abilities and personality traits over time. Although our results are informative, the present study has some limitations that we discuss in the following to encourage appropriate conclusions and inform future replication attempts (cf. Simons Shoda, & Lindsay, 2017). First, it must be cautioned some evidence for selective attrition that compromises the generalizability of our results (e.g., Lindenberger, Singer, & Baltes, 2002; Siegler & Botwinick, 1979). Our continuer sample consisted of 70% of all T1 study participants, and differed in some variables compared to the dropouts, even though the differences were in the small effect size range. Nevertheless, it should be noted that attrition is a well–known problem in aging research (e.g., McArdle, Hamagami, Elias, & Robbins, 1991) and our dropout rate is comparable with previous research (cf. Wettstein et al., 2016; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003). Moreover, such selectivity bias in longitudinal studies of older adults may also represent selectivity processes of late life where those with lower cognitive abilities, lower personal resource capacities and more health issues die earlier. Second, the sample size of the current study was rather modest and might not suffice for the detection of correlation coefficients smaller than .18. Third, the standard cross–lagged models as used in this article do not disentangle the within–person process from stable between–person differences. An alternative model that separates the within–person process from stable between–person differences through the inclusion of random intercepts is the random–intercept cross–lagged model (cf. Hamaker, Kuiper, & Grasman, 2015; Keijsers, 2016). However, while the standard cross–lagged model requires only two waves of data, the random–intercept cross–lagged model requires at least three waves of data (Hamaker et al., 2015), hence, this model approach cannot be applied to the current data.

Regarding future replication attempts, it must be noted that our sample size was rather small, so the association that we observed might differ in replications on statistical grounds. Nevertheless, we believe our results will be reproducible with healthy older adults from similar subject pools serving as participants, using cognitive tasks and self–report personality measures in the laboratory. We have no reason to believe that the results depend on other characteristics of the participants, materials, or context (cf. Simons et al., 2017).

More research, including larger samples, is needed to learn more about the longitudinal association between cognitive abilities and personality traits. In addition, future studies covering a longer follow–up period and more than two measurement occasions are desirable, because two assessments may not provide sufficient information on the unfolding of processes and their association over time (Kenny, 2005). Lastly, further studies should use (1) personality questionnaires that allow differentiating between facets, and (2) modern technologies to assess cognitive and personality–related activities on a more similar scale level.

6. Conclusion

So far, very few studies have examined cognitive abilities and personality traits in tandem in old age. The results of the present study demonstrated relatively high rank–order stabilities and stable mean levels for cognitive abilities and personality traits, except for a decrease in processing speed and an increase in neuroticism. Only two cross–lagged findings with small effect sizes were found. However, it should be noted that also small effects can have consequences, and hence merit the attention to be investigated (Ozer & Benet–Martínez, 2006; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007). In general, the two domains of functioning showed a very low degree of commonality in old age. Our results suggest more stability than change in cognitive abilities and personality traits in old age across four years. Taken together, the present study contributes to the research field (1) considering cognitive abilities as predictors of personality traits in terms of cross–lagged effects, and (2) differentiating between six different cognitive abilities.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest concerning the research, the authorship, and publication of this article.

Author Contribution

All authors contributed to the conducted research: M. Martin was responsible for study conceptualization and data collection, D. Aschwanden performed the data analyses, M. Allemand supported analyses and interpretation of data, D. Aschwanden drafted the manuscript, M. Allemand and M. Martin provided critical revisions to the manuscript. All authors approved the final version of the manuscript for submission.

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Highlights

of the Manuscript "Cognitive Abilities and Personality Traits in Old Age across Four Years: More Stability than Change"

- Few studies have examined cognition-personality associations in old age.
- The results suggest more stability than change in both domains across four years.
- The present study found few and weak associations between the two domains.
- Processing speed decreased, whereas neuroticism increased across four years.
- Reasoning was related to openness, and conscientiousness was related to verbal knowledge four years later.