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Correlated change of Big Five personality traits across the lifespan: A search for determinants

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ABSTRACT

Correlated change between different personality traits has recently caught the attention of researchers studying personality development. We conducted two studies to examine age effects (Study 1) and effects of cognitive ability (Study 2) on this phenomenon. Results indicated that correlated change was relatively stable from adolescence through adulthood, and then increased after age 70. Second, correlated change was greater among traits that have been linked to the same developmental processes (e.g., social investment or maturation of specific neurological systems). Third, cognitive ability was negatively associated with correlated change. Collectively, our findings suggest that personality change is partly driven by broad mechanisms affecting multiple traits. Associations with age and cognitive ability provide important leads regarding the possible nature of these mechanisms.

1. Introduction

Research on personality stability and change is flourishing (Denissen, van Aken, & Roberts, 2011). Knowledge about rank-order and mean-level personality development in adulthood has assumed a more concrete shape (Roberts & DelVecchio, 2000; Roberts, Walton, & Viechtbauer, 2006). One phenomenon that has recently attracted the field's attention concerns the question of whether changes in different personality traits are interrelated or independent across individuals, also known as the degree of *correlated change*. Correlated change concerns the degree to which *change*s in the level of one trait are related to *changes* in the level of another trait. For example, positive correlated change between two personality traits, such as agreeableness and conscientiousness, would indicate that the same individuals who show substantive increases in agreeableness also increase in conscientious, whereas individuals showing decreases in agreeableness also decrease in conscientiousness.

Correlated change promises interesting insights into the nature and underlying mechanisms of personality development. According to Soto and John (2012), the degree of correlated change between personality traits can be considered an informative measure indicating whether adult personality development is predominantly influenced by broadly acting mechanisms that simultaneously affect multiple trait domains, or by narrowly acting mechanisms each affecting only one single trait domain.

It should be noted that correlated change is different from trait differentiation, which refers to the extent to which traits are correlated with one another at a certain point in time. Yet, patterns of correlated change are often similar to patterns of trait differentiation (e.g., Allemand, Zimprich, & Martin, 2008). If this is the case, it is likely that a factor that caused the initial correlation simply persists across time. However, it is also possible that previously correlated traits show no correlated change, while previously uncorrelated traits may show correlated change. The first situation could indicate that a causal factor that is shared by two traits is removed or at least does not lead to similar changes in two traits across a particular period, whereas the latter situation could indicate that a new shared causal factor is introduced. Thus, correlated change and trait differentiation are two analytically independent concepts. Whereas the degree of trait differentiation is particularly informative with regard to question about the structure of personality, correlated change is important for gaining greater insight into the dynamics of personality development. The present article was dedicated to study the nature and meaning of correlated change in personality traits.

Only a handful of studies (Allemand, Zimprich, & Hertzog, 2007; Allemand et al., 2008; Soto & John, 2012) have explicitly examined this phenomenon, yielding inconsistent results. Therefore, our main research question, addressed in two large-scale longitudinal studies, was to first examine whether or not there was consistent evidence for correlated change. The heterogeneous findings of

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previous studies may also point to the existence of moderator factors. Our two-study design allowed us to examine two of such moderators. In Study 1 we examined how the degree of correlated change varied with age. In Study 2, we examined whether possible age-effects could be explained by differences in cognitive abilities. In both studies, we also examined whether there were specific trait pairs among which evidence for correlated change was stronger.

1.1. Potential sources of correlated change

A number of broadly acting mechanisms affecting multiple trait domains have been proposed as sources of correlated change. There are, for instance, several theoretical reasons to expect associations among changes in agreeableness, conscientiousness, and emotional stability. Digman (1997) proposed that changing to a personality profile consistent with socially approved behavior would be reflected in mean-level increases in the three aforementioned trait-domains. Thus, socialization might be a broad-acting developmental process responsible for correlated change among these traits. In a somewhat related manner, a prominent theoretical principle of personality development, the Social Investment Principle (SIP; Roberts, Wood, & Smith, 2005), holds that transitions to, and increased investment in normative roles of adult social life (e.g., starting a career, a serious relationship, or a family) predict changes in agreeableness, conscientiousness, and emotional stability. Finally, it has been argued that the aforementioned three traits are all related to the serotonergic neurobiological system (DeYoung & Gray, 2009; DeYoung, Peterson, & Higgins, 2002).

There are also theoretical grounds to assume that changes in extraversion and openness would be related to one another. Specifically, Digman (1997) proposed associations among these traits because both traits have linkages with the broad concept of personal growth and self-actualization. Personal growth involves exploration, which, in turn, is linked to the dopaminergic neurobiological system. Hence, along the same lines, DeYoung et al. (2002); DeYoung & Gray, (2009)) proposed that the dopaminergic system might simultaneously affect extraversion and openness.

Neurobiological systems such as the dopaminergic system are known to change throughout the lifespan (e.g., Weickert et al., 2007). If the abovementioned theoretical ideas would hold, then changes in, for example, the dopaminergic system should affect levels of extraversion and openness simultaneously producing correlated change between these two traits. Similarly, mechanisms affecting agreeableness, conscientiousness, and emotional stability simultaneously should lead to correlated change between these three traits. Thus, there are several reasons to expect correlated change in general, with the strength of the correlated change being dependent on the particular trait pair that is considered.

1.2. Previous research on correlated change

There already is some research that has addressed the concept of correlated change. The first of these studies (Allemand et al., 2007) focused on cohorts of middle-aged individuals (i.e., 42–46 years of age) and older individuals (i.e., 60–64 years of age). In both cohorts, there was a considerable amount of correlated change across a four-year period. In particular, changes in emotional stability were strongly associated with changes in extraversion and conscientiousness, and changes in extraversion and conscientiousness were also strongly associated with one another. The overall amount of correlated change appeared to be about equal in the two age cohorts.

The older cohort was reassessed 8 years later, which allowed Allemand et al. (2008) to examine correlated change in older individuals across a 12-year period. Interestingly, this follow-up yielded quite different results, despite that the same analyses were applied. That is, changes in emotional stability were no longer significantly associated with changes in other Big Five traits. However, changes in all other Big Five traits were substantially associated with one another. Especially the amount of correlated change of conscientiousness with extraversion and agreeableness was considerable, with coefficients larger than .60. The fact that the patterns of correlated change observed in the same cohort across 4 years did not replicate across 12 years might suggest that the interval between measurement occasions plays a role.

Adding to the inconsistency observed in previous studies, a recent third study examining correlated change between ages 21 and 61 (Soto & John, 2012) found no evidence for correlated change in Big Five traits at all. However, this study employed a small non-representative sample exclusively consisting of women who graduated from college in the 1960s. As a result of the multiple differences in sample composition, the discrepancies between the amounts of correlated change reported by Soto and John (2012) and Allemand et al. (2007, 2008) might be due to age differences, gender differences, and differences in educational level between samples. Furthermore, the possibility that broad mechanisms may lead to greater amounts of correlated change in some trait pairs than in others has not been formally tested. Finally, and perhaps most importantly, the inconsistency in the findings of previous studies suggests that it may also be warranted to examine possible moderators of correlated change.

1.3. Potential moderators of correlated change

A comparison of the samples that were employed in previous studies on correlated change already provides some leads of what factors may have contributed to their inconsistent results. First, the samples were differently aged. There are theoretical reasons for why age might be an important moderator of correlated change and may hence have contributed to inconsistency in findings across previous studies. That is, the aforementioned developmental mechanisms may be more active and neurobiological systems may undergo more changes at particular points in the lifespan. In this context, it may already be worth mentioning that the previously discussed SIP mainly applies to young adults (Roberts et al., 2005). This is because the transitions to and increases in investment in social roles of adult life, which are thought to cause increases in agreeableness, conscientiousness, and emotional stability, mainly take place in young adulthood (Roberts et al., 2005). Furthermore, there generally is more change in the structure of neural systems, and hence likely also more change in neurobiological systems, in adolescence and late adulthood/old age than in early and middle adulthood (Giedd et al., 1999; Ziegler et al., 2012). Thus, if broadly acting mechanisms such as the SIP and neurobiological systems are indeed responsible for producing correlated change, the strength of correlated change should mirror developmental trends in these systems. In that case, it is likely that there are curvilinear age-related patterns of correlated change with the highest levels in the period from adolescence to young adulthood and in late adulthood.

Furthermore, developmental processes in personality are often thought to be related or even partly attributable to changes in cognitive ability. For instance, the finding that trait differentiation among the Big Five is low in adolescence, increases towards middle adulthood, and increases again from late adulthood onwards, has often been explained as a consequence of developmental increases in general cognitive ability and verbal comprehension (Allik, Laidra, Realo, & Pullmann, 2004; Soto, John, Gosling, & Potter, 2008). Indeed, several studies have reported more trait differentiation in individuals with high cognitive abilities versus individuals with lower cognitive abilities (Austin et al., 2002; Bowler, Bowler, & Phillips, 2009; Di Blas & Carraro, 2011; Mottus, Allik, & Pullmann, 2007; Toomela, 2003). Yet, there is also a number of studies (Austin, Deary, & Gibson, 1997; Mottus et al., 2007; Rammstedt, Goldberg, & Borg, 2010) that found no evidence for associations of cognitive abilities with trait differentiation.

Though some findings suggest that cognitive ability may play a role in the structural links among traits, it is yet unclear whether possible age-related patterns in associations between *changes* in traits (i.e., correlated change) can also be explained by differences in cognitive abilities. The present study provides a first attempt to examine whether there are any effects of age on correlated change and, if so, whether these age effects are consistent with differences in cognitive abilities.

1.4. The present research

The primary goal of the present research is to obtain greater insight into correlated change among Big Five traits. In two studies, we will examine the extent to which there is evidence for correlated change. In addition, we will examine whether correlated change among trait pairs that have been linked to the same developmental processes (Agreeableness-Conscientiousness-Emotional Stability, and Extraversion-Openness) is greater than among trait pairs of which the traits have been linked to different processes. Specific features of the two studies allow us to examine the role of two potential moderators of correlated change. Specifically, Study 1 employs a large nationally representative German dataset ($N = 14{,}886$) that covered ages 17–96, enabling us to examine the effects of age on correlated change. Study 2 examined the effects of verbal and non-verbal cognitive ability on correlated change in a sample of German adolescents ($N = 174$). Specific hypotheses regarding both studies will be provided in the introduction to each of these studies.

2. Study 1: correlated change across the lifespan

Study 1 investigated age differences in correlated change in a large and representative sample ($N = 14{,}886$), covering the entire adult lifespan. This way, we were able to examine how much evidence there was for correlated change in general. In addition, the wide age range allowed us to directly examine age effects on patterns of correlated change. By using a representative design, we could further be more confident that results generalize to the broader population.

Due to inconsistency in their results, previous studies provided few leads as to what to expect with regard to the amount of correlated change in general. However, broad mechanisms affecting multiple traits, and hence producing correlated change, have been proposed (DeYoung & Gray, 2009; DeYoung et al., 2002; Digman, 1997; Roberts et al., 2005). In addition, 2 out of 3 previous studies found evidence for correlated change. Therefore, we expect to find correlated change, especially among trait pairs that have been linked to the same developmental process and neurobiological system. Thus, we hypothesize more correlated change between agreeableness and conscientiousness, agreeableness and emotional stability, conscientiousness and emotional stability, and extraversion and openness than among other trait pairs. With regard to age differences, it should be noted that specific neurobiological changes (e.g., decreases in gray matter; Ziegler et al., 2012) and particular socialization processes (e.g., Social Investment; Roberts et al., 2005) are more pronounced in particular periods in specific periods in the lifespan. For that reason, we anticipated more correlated change in the period from adolescence and young adulthood, and in old age (i.e., after age 60) when compared to middle adulthood.

3. Method

3.1. Participants and procedure

Analyses were based on the German Socio-Economic Panel (SOEP). The SOEP contains an ongoing longitudinal representative large-scale assessment of private households in Germany since 1984. Information was gathered through interviews or via questionnaires in 2005 and 2009. Only the 14,886 individuals with information on at least 3 of the Big Five scales at each of the two measurement occasions as well as information on age and gender were included. We divided participants into fourteen cohorts based on their age at Time 1 with each cohort covering 5 years (see Table 1).

Among the included individuals, there were no biases related to missing values on the Big Five, as Little's Missing Completely at Random test (Little, 1988) revealed a normed chi-square (χ^2/df) of 1.43. According to guidelines by Bollen (1989), this suggests that estimating missing values is justified. For this purpose, we used the Expectation Maximization (EM) algorithm in our analyses.

3.2. Measures

3.2.1. Personality

The two waves of the SOEP in 2005 and 2009 contained a short version of the German Big Five Inventory, the BFI-S (Gerlitz & Schupp, 2005). The instrument measures the Big Five personality traits (neuroticism, extraversion, openness, agreeableness, conscientiousness) with three items for each dimension. Participants rated their agreement on a scale ranging from 1 ("Does not apply to me at all") to 7 ("Applies to me perfectly"). Examples of itemsare: "I see myself as someone who worries a lot" (neuroticism), "I see myself as someone who is reserved" (extraversion, reversed item), "I see myself as someone who has an active imagination" (openness to experience), "I see myself as someone who has a forgiving nature" (agreeableness), and "I see myself as someone who does things efficiently" (conscientiousness). We reversed the responses to the neuroticism items to capture emotional stability before including them in subsequent analyses. Internal consistencies ranged from $\alpha = .51$ to .66. Comparable consistency values of the BFI-S have been reported elsewhere in SOEP based papers (Dehne & Schupp, 2007). Moderate consistency values result from the briefness of the instrument, which tries to guarantee content validity for those broad multifaceted traits within harsh measurement length restrictions that are typical for large-scale studies like the SOEP.

4. Results

We ran 10 multigroup cross-lagged panel models in Mplus 7 (Muthén & Muthén, 2012) to examine correlated change simultaneously in the aforementioned nine age cohorts. Each model contained two consecutive measurement occasions of two Big Five traits, in such a way that each Big Five trait was paired with each of the other four Big Five traits, resulting in a total of 10 models. The estimated models (see Fig. 1) contained the stability paths of Big Five traits, initial (i.e., Time 1) correlations, and the Time 2 residual correlations reflecting correlated change (e.g., Neyer & Asendorpf, 2001). Although not in the focus of our interest, we also included the cross-lagged paths from one trait on the other to ensure an unambiguous interpretation of the correlated change coefficients (a table containing the cross-lagged effects is included as supplementary material). Generally, the inclusion of cross-lagged paths in our models had a minimal effect on correlated change coefficients. It is also essential to note that our models

Table 1
Initial correlations and correlated change in fourteen different age cohorts in Study 1.

	N	% men	Em-Ex	Em-Op	Em-Ag	Em-Co	Ex-Op	Ex-Ag	Ex-Co	Op-Ag	Op-Co	Ag-Co	Sero/SIP	Dopa	Other	Mean
Initial correlation																
<20	612	50.0	.19***	.00	.08	.03	.33***	.05	.15***	.13**	.17***	.29***	.13	.33	.12	.14
20–24	888	47.9	.24***	.06	.11**	.15***	.39***	.11***	.12***	.18***	.11**	.39***	.22	.39	.14	.19
25–29	935	43.5	.18***	.04	.15***	.19***	.33***	.04	.14***	.11***	.12***	.29***	.21	.33	.11	.16
30–34	1066	47.1	.11***	.03	.13***	.06*	.30***	.07*	.19***	.12***	.17***	.31***	.17	.30	.12	.15
35–39	1503	46.6	.15***	.06*	.10***	.10***	.36***	.13***	.22***	.18***	.17***	.31***	.17	.36	.15	.18
40–44	1660	48.7	.16***	.03	.10***	.13***	.40***	.11***	.22***	.12***	.22***	.30***	.18	.40	.14	.18
45–49	1554	46.9	.09***	.04	.11***	.09***	.35***	.11***	.21***	.12***	.18***	.32***	.17	.35	.13	.16
50–54	1385	46.4	.18***	.12***	.10***	.07**	.34***	.13***	.20***	.14***	.16***	.28***	.15	.34	.16	.17
55–59	1218	49.9	.14***	.15***	.17***	.17***	.40***	.09**	.21***	.10***	.14***	.35***	.23	.40	.14	.19
60–64	1236	49.5	.14***	.12***	.14***	.08**	.35***	.09**	.17***	.11***	.17***	.33***	.18	.35	.13	.17
65–69	1297	49.7	.14***	.08**	.08**	.06*	.40***	.07*	.21***	.09**	.17***	.34***	.16	.40	.13	.16
70–74	746	48.5	.18***	.09*	.13***	.10**	.38***	.09**	.18***	.11**	.24***	.36***	.20	.38	.15	.19
75–79	466	42.9	.17***	.06	.00	.08	.45***	.15**	.23***	.12**	.25***	.35***	.14	.45	.16	.19
>80	320	35.0	.24***	.16**	.15**	.09	.44***	.17**	.27***	.02	.25***	.33***	.19	.44	.19	.21
Total sample	14,886	47.4	.16***	.08***	.11***	.09***	.37***	.09***	.18***	.12***	.16***	.32***	.17	.37	.13	.17
Correlated change																
<20	612	50.0	.14***	.04	.17***	.15***	.26***	.09*	.08	.09*	.07	.35***	.22	.26	.09	.14
20–24	888	47.9	.21***	.03	.09**	.14***	.19***	.07*	.15***	.13***	.14***	.19***	.14	.19	.12	.13
25–29	935	43.5	.12***	.03	.11***	.14***	.23***	.03	.15***	.07	.08*	.22***	.16	.23	.08	.12
30–34	1066	47.1	.11***	-.03	.04	.12***	.25***	.11***	.14***	.13***	.09**	.30***	.15	.25	.09	.13
35–39	1503	46.6	.15***	.02	.13***	.07**	.29***	.13***	.14***	.08**	.11***	.25***	.15	.29	.11	.14
40–44	1660	48.7	.14***	.03	.09***	.08**	.23***	.09***	.15***	.10***	.09***	.27***	.15	.23	.10	.13
45–49	1554	46.9	.10***	.09***	.07**	.08**	.23***	.09***	.21***	.08**	.09***	.23***	.13	.23	.11	.13
50–54	1385	46.4	.11***	.00	.10***	.08**	.25***	.08***	.14***	.10***	.15***	.23***	.14	.25	.10	.12
55–59	1218	49.9	.06*	.01	.08**	.02	.27***	.11***	.17***	.17***	.12***	.26***	.12	.27	.11	.13
60–64	1236	49.5	.13***	.06*	.07*	.05	.32***	.05	.19***	.08**	.11***	.22***	.11	.32	.10	.13
65–69	1297	49.7	.14***	.03	.09**	.06*	.27***	.09**	.19***	.04	.13***	.30***	.15	.27	.10	.13
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75–79	466	42.9	.06	.04	.11*	.05	.25***	.16***	.26***	.12**	.21***	.30***	.15	.25	.14	.16
>80	320	35.0	.19***	.05	.16**	.15*	.34***	.06	.34***	.13*	.32***	.23***	.18	.34	.18	.20
Total sample	14,886	47.4	.13***	.03***	.09***	.08***	.26***	.08***	.16***	.09***	.12***	.25***	.14	.26	.10	.13

Note. Em = Emotional Stability; Ex = Extraversion; Op = Openness; Ag = Agreeableness; Co = Conscientiousness; Values in the "Sero/SIP" column refer to the average initial correlation or correlated change among the trait pairs emotional stability – agreeableness, emotional stability – conscientiousness, and agreeableness –conscientiousness; Values in the "Dopa" column refer to the initial correlation or correlated change among extraversion and openness; Values in the "Other" column refer to the average initial correlation or correlated change among trait pairs not associated with the serotonergic system and SIP, or the dopaminergic system.
*** $p < .001$.
** $p < .01$.
* $p < .05$.

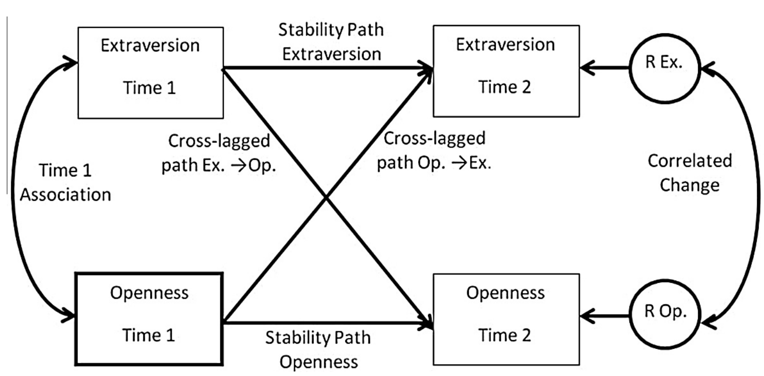

Fig. 1. Sample cross-lagged model. Ex. = Extraversion; Op. = Openness; R = Residual.

allowed us to examine the amount of correlated change while explicitly controlling for initial amounts of trait differentiation. Therefore, both phenomena were examined independent of one another.

Because all variables in the models were associated with one another, these models were fully saturated. Hence, they had zero degrees of freedom and provided, by definition, a perfect fit to the data.

For the purpose of the present study, we were mainly interested in correlated change coefficients among the Big Five. These coefficients, together with initial correlations, are presented in Table 1. This table reveals that across age cohorts, the initial level of one trait was almost always (i.e., in 125 out of 140 cases) associated with the initial levels of other traits. Furthermore, we found clear evidence for correlated change across age cohorts, as relative changes in one trait were significantly positively associated with relative changes in other traits in 83% (i.e., 116 of the 140) cases. There were a few exceptions to this general pattern. Relative changes in emotional stability were not correlated with changes in openness in 11 of the 14 age cohorts. The same was true for emotional stability and conscientiousness, which were not significantly associated in 3 of the 14 age cohorts, and only weakly associated in another 3 age cohorts. Likewise, relative changes in extraversion were not significantly associated (i.e., in 4 of the 14 age cohorts) or only weakly (i.e., in 2 of the 14 age cohorts) associated with relative changes in agreeableness.

In Fig. 2, we plotted the mean magnitude of correlated change across all trait-pairs across the lifespan and found a relationship between the degree of correlated change and participant's age. Specifically, Fig. 2 suggests a curvilinear pattern of correlated change across the life span with stable levels of correlated change from adolescence through middle adulthood, followed by an increase towards old age. For a more formal test, we Fisher-*z*-transformed both initial correlations and correlated change coefficients and used these numbers as outcome variables in Repeated measures ANalyses Of VAriance (RANOVAs) with age-cohorts as measurement occasions. These analyses confirmed that the association between age and correlated change was best-characterized by a quadratic (i.e., curvilinear) function ($F(1,9) = 15.25$; $p = .004$; partial $\eta^2 = .63$).

Age-patterns for correlated change in trait pairs that have been linked to the serotonergic system and the SIP (i.e., agreeableness, conscientiousness and emotional stability), the trait-pair that has been linked to the dopaminergic system (i.e., extraversion-openness), and other random trait pairs (i.e., the pairs that have not been linked to theoretically proposed mechanisms), are shown in Table 1 and plotted in Fig. 2. RANOVAs confirmed that correlated change among trait pairs linked to the serotonergic system and the SIP was well-captured with a quadratic (i.e., curvilinear) function ($F(1,2) = 94.74$; $p = .010$; partial $\eta^2 = .98$) with relative large amounts of correlated change in late adolescence, decreases towards middle adulthood, and increases towards old age.

The association between age and correlated change in the trait-pair that has been linked to the dopaminergic system (i.e., extraversion-openness) could not be examined with a RANOVA, as RANOVAs require variance at all levels (in this case also multiple trait-pairs). Therefore, we conducted a hierarchical regression analysis with a centered age variable (for linear effects) and a squared centered age variable (for quadratic effects) as predictors and correlated change of extraversion with openness as dependent variable. This analysis showed that the linear term explained a significant proportion of the variance in correlated change between extraversion and openness ($\beta = .654$; $R^2 = .428$; $p = .011$), whereas adding a quadratic term did not explain a significant proportion of additional variance ($\Delta R^2 = .020$; $p = .542$). Thus, as can be seen in Fig. 2, there is a roughly linear increase in the amount of correlated change between trait-pair that has been linked to the dopaminergic system.

Finally, there was some evidence that the association between age and correlated change among trait pairs other than the aforementioned could be captured with a quadratic (i.e., curvilinear) function in a RANOVA ($F(1,5) = 10.72$; $p = .022$; partial $\eta^2 = .68$). In this case, the amount of correlated change was relatively small until age 65. After that age, correlated change increased.

5. Discussion of Study 1

Study 1 examined age differences in correlated change in a large and representative sample. Our results clearly show that there is evidence for correlated change in all of the considered age groups. However, it should be noted that correlated change coefficients are generally rather modest (i.e., <.15) at most stages in the lifespan. Thus, it seems that personality change is partly, but by no means entirely, driven by broad mechanisms affecting multiple traits.

Overall, the pattern of correlated change appeared to be largely similar to the pattern of trait differentiation, suggesting that factors that caused initial correlations likely generally persisted over time. Further results provided some clues of what these factors might be. That is, there was some evidence for greater correlated change among trait pairs previously associated with the same broad mechanisms (trait pairs linking agreeableness, conscientiousness and emotional stability to one another and the trait-pair extraversion-openness) when compared to trait pairs that have not been associated with such mechanisms. However, it should be noted that the larger average correlated change among trait pairs linking agreeableness, conscientiousness, and emotional stability is largely driven by the trait pair agreeableness-conscientiousness. Still, the pattern of findings of the present study nicely connects with research suggesting that agreeableness, conscientiousness, and emotional stability are associated with the serotonergic

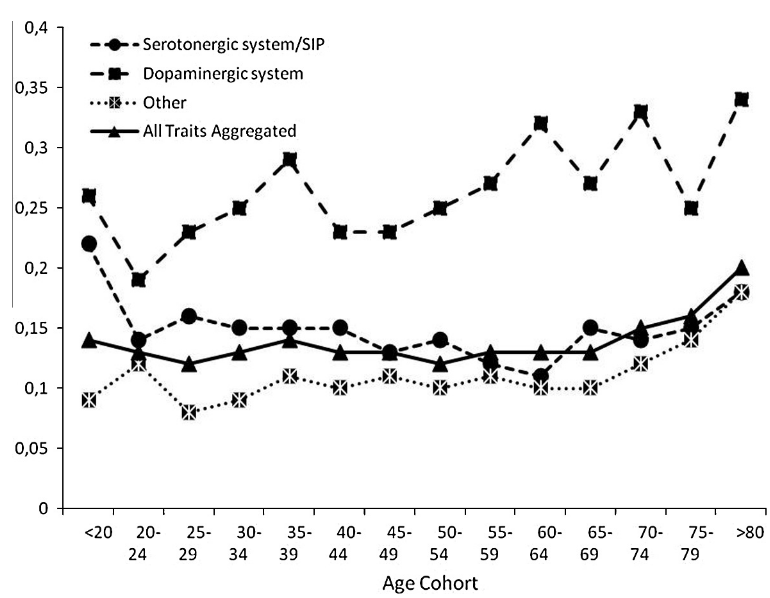

Fig. 2. Average correlated change across trait pairs associated with the Social Investment Principle and the serotonergic system (Emotional Stability – Agreeableness, Emotional Stability – Conscientiousness, and Agreeableness – Conscientiousness), the dopaminergic system (Openness – Extraversion), other trait pairs (those not associated with the Social Investment Principle, the serotonergic system, or the dopaminergic system), and all traits pairs.

system, whereas extraversion and openness have both been linked to the dopaminergic system (DeYoung & Gray, 2009; DeYoung et al., 2002). Therefore, changes in these neurobiological systems might be responsible for increased correlated change among the aforementioned trait pairs.

It should be noted that evidence for increased correlated change among trait pairs linking agreeableness, conscientiousness and emotional stability relative to correlated change among traits with no theoretical linkages was greatest between ages 25 and 45, and around age 65. According to the Social Investment Principle (Roberts et al., 2005), these traits are the most likely to change simultaneously as a result of transitioning to roles of adult social life (e.g., investing in a stable romantic relationship, having children, getting a job). Transitions into those roles are most common between age 25 and 45 (e.g., Bleidorn et al., in press), whereas transitioning out of at least one of these role (i.e., a job) is common around age 65 because of retirement. Thus, transitions in and out of roles of adult social life may also act as broad mechanisms causing increased correlated personality change between agreeableness, conscientiousness, and emotional stability at some stages during the lifespan.

Correlated change between the trait-pair that has been associated with the dopaminergic system (i.e., extraversion-openness) increased in a roughly linear manner with age. Therefore, it may be that the impact of broad mechanisms relative to specific mechanisms on development of extraversion and openness gradually increases with age. Changes in the dopaminergic system itself could be responsible for this increased correlated change, as this system is known to change substantively from adulthood to old age (Weickert et al., 2007). In other periods in the lifespan (e.g., from young adulthood to adulthood) less changes in this system have been found, which might be the reason that there is somewhat less correlated change between extraversion and openness in those periods.

The overall degree of correlated change appeared to vary across the lifespan. Specifically, a quadratic relation between age and correlated change suggests that the amount of correlated change is relatively stable from adolescence through middle adulthood, but clearly increases in old age. As previously explained, this may be caused by broad mechanisms that may drive changes in multiple traits being more active in some periods of the lifespan than in others.

In addition to broad mechanisms driving changes in multiple traits, increases in correlated change in old age may also partly represent methodological artifacts that are related to item comprehension. That is, it may be that older individuals experience broad cognitive changes that are associated with a shift in their ability to distinguish between items of different personality factors. Such lifespan changes in cognitive ability have indeed been reported (Li et al., 2004). This means that the increase of correlated change during old age might reflect common decreases in cognitive ability during that period in life. In Study 2, we addressed this possible interpretation by examining the association between cognitive ability and correlated change.

Much like old age, the period of adolescence is also characterized by substantial changes in cognitive ability (e.g., Li et al., 2004). However, unlike in old age, increases instead of decreases in cognitive ability are typical for this period in the lifespan. Unfortunately, the youngest individuals in Study 1 were already 17 years old when they participated, which implies that it is likely that we have missed much of such possible changes.

In view of the strong increases in cognitive ability during adolescence, examining age trends in correlated change throughout this life stage would offer an interesting opportunity to shed further light on the potential associations between correlated change and cognitive ability. In addition, adolescence is characterized by tremendous changes in other areas of development, such as the initiation of identity development (Erikson, 1950), a shifting orientation from parents to peers (Furman & Buhrmester, 1992), but also changes toward an adult posture (Petersen, Crockett, Richards, & Boxer, 1988), and brain development (Giedd et al., 1999). With all these phenomena, individual differences in the timing have been observed. Thus, possible broad mechanisms producing correlated change may be more active; or active at different ages in some adolescents when compared to others. Therefore, adolescence is an excellent period to study correlated change and possible individual difference herein. Because of this, in Study 2 we followed individuals across adolescence.

6. Study 2: effects of cognitive ability

As stated, age differences in correlated change may be a function of developmental changes in cognitive ability. For example, one might gain a more differentiated view of one's changing personality once cognitive ability increases. Study 2 set out to test this possibility in a sample of adolescents.

During early adolescence, individuals are developing the cognitive maturity that is necessary for fine-grained and differentiated personality self-descriptions (Soto et al., 2008). Accordingly, intellectual ability should be more of a bottleneck during this age period, making it ideal to test whether differences in ability are reflected in differences in correlated change. If our interpretation of age-related changes in correlated change as a result of changes in cognitive abilities would hold, individuals with higher levels of cognitive abilities should exhibit less correlated change. This interpretation is backed up by previous studies on personality trait differentiation suggesting that individuals with higher levels of cognitive abilities exhibit more personality trait differentiation (Austin et al., 2002; Bowler et al., 2009; Di Blas & Carraro, 2011; Mottus et al., 2007; Toomela, 2003). The current study will be the first to explicitly test the association between correlated change and cognitive ability.

When considering cognitive ability, one can focus on verbal IQ, performance IQ, or overall IQ estimates. Personality measures are typically based on verbal item endorsement (e.g., Goldberg, 1993). Therefore, individuals with better verbal comprehension (i.e., a higher verbal IQ) should be better able to understand personality questionnaires (Soto et al., 2008). It thus seemed reasonable to expect that verbal IQ is a better predictor of personality trait differentiation and correlated change when compared to performance IQ. The present study tested this assertion.

7. Method

7.1. Participants and procedure

Participants were part of the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC). The sample originally consisted of 230 children (51.7% boys) who were studied annually from their first or second year in preschool until age 12. Because the schools were selected from a broad spectrum of neighborhoods, the sample was relatively unbiased. Over 90% of the approached parents gave their consent for their child's participation. Until age 12, attrition was low (19% over 8 years) and unsystematic (see Weinert & Schneider, 1999, for this initial part of the study). After age 12, individuals were reassessed at age 17. Only 6% of the participants dropped out after age 12, resulting in 174 participants at age 17.

7.2. Measures

7.2.1. Personality

At ages 12 and 17, all 174 participants rated their own personality on a Big Five questionnaire. Each scale consisted of 8 bipolar adjectives that were balanced with regard to the social desirability of the items. The items were answered on a 5-point scale (with labels "very much like the left item pole", "somewhat like the left item pole", "neither/nor", "somewhat like the right item pole", "very much like the right item pole"). Sample items are "balanced-tense" (neuroticism), "silent-talkative" (extraversion), "unimaginative-imaginative" (openness), "stubborn-gentle" (agreeableness), and "imprecise-picky" (conscientiousness). For more information on the development of this questionnaire, see Asendorpf and van Aken (1999). The internal consistencies (Cronbach's alphas) of the resulting 8-item scales were satisfactory, ranging from .68 to .83 at age 12, and from .75 to .88 at age 17.

7.2.2. Intelligence

At age 12 and 17, performance intelligence was assessed with the non-verbal Series, Classifications, Matrices, and Topologies scales of the Culture Fair Intelligence Test (CFT-20; Weiß, 1987; $\alpha = .81$). Verbal intelligence was assessed with the vocabulary subtest of the German revised Wechsler Intelligence Test for Adults (HAWIK-R for 12-year olds, $\alpha = .81$).

8. Results

To examine the impact of cognitive abilities on correlated change among Big Five traits, we first performed a median split procedure on adolescents verbal and performance intelligence quotients (IQs). For verbal IQ, the group with a high IQ ($M = 119.92$; $SD = 8.31$) consisted of 86 adolescents, whereas the group with an average IQ ($M = 99.33$; $SD = 6.87$) consisted of 88 adolescents. With regard to performance IQ, the high group ($M = 125.44$; $SD = 9.08$) consisted of 92 adolescents, whereas the average group ($M = 103.73$; $SD = 7.18$) consisted of 82 adolescents. These groups were used in two sets of multigroup cross-lagged models. As each model contained 2 consecutive measurement occasions of two Big Five traits, they were virtually identical to the models described in Study 1. The only difference was that we distinguished two groups (i.e., high verbal IQ versus average verbal IQ, or high performance IQ versus average performance IQ) in each of the models. Similar to Study 1, all of the models were fully saturated and had, by definition, a perfect fit to the data.

Like in Study 1, our main focus was on correlated change among the Big Five traits. Correlated change coefficients, as well as initial correlations, are shown in Table 2. As a general rule, there was strong evidence for correlated change across traits between ages 12 and 17 across all groups. Exceptions to this general rule were the trait pairs of agreeableness-conscientiousness and extraversion-conscientiousness, for which there was no evidence for correlated change. In addition, correlated change of openness with agreeableness was only evident in one of the four groups, whereas correlated change of emotional stability with conscientiousness and extraversion with openness was only evident in three of the four groups. Changes in other pairings of traits were significantly correlated with one another in all four groups.

There was some evidence that there was more correlated change in the trait pair extraversion-openness than in other trait pairs, but this evidence was restricted to the average verbal IQ and the average performance IQ groups. No evidence was found for increased correlated change among trait pairs linking agreeableness, conscientiousness, and emotional stability to one another.

After initial correlations and correlated change coefficients were Fisher-*z*-transformed and entered in a data-matrix, we formally compared the relation between IQ on the one hand, and initial correlations and correlated change coefficients on the other hand by means of four Paired Samples *T*-Tests. A first *T*-Test showed that initial correlations were lower in the high verbal IQ than in the average verbal IQ group ($t(9) = -2.694$; $p = .025$; $d = 0.62$). Similarly, the high performance IQ group displayed lower initial correlations among trait pairs than the average performance IQ group ($t(9) = -6.879$; $p < .001$; $d = 1.38$).

With regard to correlated change, the same pattern emerged. That is, the high verbal IQ group displayed less correlated change than the average verbal IQ group ($t(9) = -2.880$; $p = .018$; $d = 0.77$). Again, the same pattern was also found for performance IQ, with the high performance IQ group exhibiting less correlated change than the average performance IQ group ($t(9) = -2.400$; $p = .040$; $d = 0.58$).

9. Discussion of Study 2

Study 2 supported the assumption that correlated change varies as a function of an individual's cognitive ability. Moreover, this appears to be the case for both verbal and performance ability. Therefore, it seems reasonable to conclude that during adolescence, an age during which emerging cognitive abilities may still constitute a bottleneck for trait comprehension, correlated change may partly be a result of general cognitive limitations.

It is important to note that results from Study 2 are based on data from a sample of early to middle adolescents. As adolescence is a time of tremendous changes and rapidly changing cognitive abilities (e.g., Li et al., 2004), this finding supports the assumption that the curvilinear age pattern of correlated change revealed in Study 1 may in fact be partly a function of this underlying cognitive substrate. This would be consistent with the results of previous studies that found associations between cognitive ability and within-time trait differentiation (Austin et al., 2002; Bowler et al., 2009; Di Blas & Carraro, 2011; Mottus et al., 2007; Toomela, 2003).

Generally, we again found that patterns of correlated change largely corresponded with patterns of trait differentiation. Furthermore, we also found some evidence for increased correlated change among trait pairs that have previously been linked to the same broad mechanism. However, this evidence was limited to the trait pair extraversion-openness, and was only evident among individuals with lower cognitive abilities (both verbal and performance). This suggests that correlated change in extraversion and openness may be caused by individuals having particular problems in distinguishing the adjectives associated with each of these two traits. Thus, language comprehension might play a role. Therefore, correlated change across all trait pairs and among particular trait pairs associated with theoretically proposed mechanisms may at least be partly a result of cognitive limitations.

10. General discussion

In order to understand developmental processes in personality across the lifespan, it is important to examine to what extent these processes are driven by mechanisms affecting multiple traits at the same time and narrowly operating mechanisms affecting single traits. The first position would imply substantial correlated change among all or sets of Big Five personality traits, whereas the second position would imply that changes in Big Five traits are independent from one another. Previous research (Allemand et al., 2007; Allemand et al., 2008; Soto & John, 2012) yielded inconsistent results. We found consistent evidence for correlated change in two longitudinal studies, although it should be noted that the size of the correlated change coefficients generally was rather modest. There was some evidence that correlated change was higher in trait pairs that have previously been associated with broad mechanisms that may produce personality change. Most importantly, we found that correlated change was substantially related to age,

Table 2
Initial correlations and correlated change in a group with high cognitive abilities and a group with average verbal and performance cognitive abilities.

	Em-Ex	Em-Op	Em-Ag	Em-Co	Ex-Op	Ex-Ag	Ex-Co	Op-Ag	Op-Co	Ag-Co	Sero/ SIP	Dopa	Other	Overall mean
Initial correlations														
Verbal high	.47***	.16	.33***	.17	.21*	.37***	.06	.01	.28**	.27**	.26	.21	.23	.23
Verbal average	.69***	.46***	.38***	.20	.44***	.36***	.06	.04	.45***	.26*	.28	.44	.34	.33
Performance high	.51***	.21*	.19	.14	.27**	.27**	.08	-.07	.26**	.23*	.19	.27	.23	.22
Performance average	.65***	.44***	.53***	.23*	.35***	.49***	.30**	.28**	.42***	.36***	.37	.35	.43	.41
Total sample	.57***	.34***	.35***	.19*	.30***	.39***	.20***	.09	.34***	.30***	.28	.30	.32	.31
Correlated change														
Verbal high	.34***	.32***	.27**	.09	.15	.25*	-.02	.04	.22*	.09	.15	.15	.20	.18
Verbal average	.52***	.44***	.29**	.32***	.51***	.21*	.06	.03	.38***	.13	.25	.51	.27	.29
Performance high	.37***	.40***	.31**	.20*	.22*	.21*	.01	.09	.27**	.13	.21	.22	.23	.22
Performance average	.49***	.38***	.28**	.23*	.46***	.25*	.11	.28**	.36***	.08	.20	.46	.32	.29
Total sample	.43***	.39***	.27***	.22**	.33***	.24**	.06	.16*	.30***	.11	.20	.33	.26	.25

Note. Em = Emotional Stability; Ex = Extraversion; Op = Openness; Ag = Agreeableness; Co = Conscientiousness; Values in the "Sero/SIP" column refer to the average initial correlation or correlated change among the trait pairs emotional stability – agreeableness, emotional stability – conscientiousness, and agreeableness –conscientiousness; Values in the "Dopa" column refer to the initial correlation or correlated change among extraversion and openness; Values in the "Other" column refer to the average initial correlation or correlated change among trait pairs not associated with the serotonergic system and SIP, or the dopaminergic system.
*** $p < .001$.
** $p < .01$.
* $p < .05$.

which, in turn, might be partly a result of developmental changes in cognitive abilities. Below, findings and their implications will be discussed in detail.

First and foremost, we found clear evidence for the existence of correlated change among the Big Five. Specifically, in a large and representative study, significant correlated change among Big Five personality traits was found from adolescence to old age (Study 1). In addition, correlated change was found in individuals with high and low levels of cognitive ability (Study 2). It therefore seems fair to conclude that, in addition to narrowly operating mechanisms affecting single traits in unique ways, there also seem to be broadly acting mechanisms simultaneously affecting change in multiple traits.

Given the generally rather modest size of the correlated change coefficients, it does seem that narrowly acting mechanisms (i.e., contributing to orthogonality) may have more of an impact on personality change in particular traits than broad acting mechanisms do. Still, uncovering broadly acting mechanisms likely provides valuable insights in the causes of personality change. As patterns of initial correlations were largely similar to patterns of correlated change, the factors or broad mechanisms that may drive the associations between traits are likely to be relatively stable across time within age-cohorts.

One broad acting mechanism may be related to both extraversion and openness. That is, there was evidence for correlated change among these traits, especially in Study 1. Both traits have been linked to the dopaminergic system (DeYoung & Gray, 2009; DeYoung et al., 2002), which makes this system a possible candidate as a broad mechanism affecting both extraversion and openness. There was less evidence for consistently increased correlated change among agreeableness, conscientiousness, and emotional stability across the lifespan.

The just-described findings apply to the broad picture of correlated change across the lifespan. However, our study design also allowed us to examine whether or not the amount of correlated change was age-graded and whether it occurred to the same degree among individuals with different levels of cognitive ability.

10.1. Age and cognitive ability

Age-related patterns in correlated change were best described by a quadratic trend indicating that the amount of correlated change was relatively stable from adolescence through adulthood, but increased in old age. This age-related trend in correlated change seems to mirror age-related patterns typically observed for cognitive ability (e.g., Craik & Bialystok, 2006). This may suggest that cognitive ability could be an important explanatory factor in this regard. Performal aspects of cognitive ability (e.g., reasoning, memory) decline from adulthood to old age whereas more verbal aspects (e.g., verbal knowledge and fluency) remain relatively stable (Li et al., 2004). Given the similarities in developmental patterns of performal IQ factors and correlated change, one could expect correlated change to be stronger associated with performal IQ than for verbal IQ. On the other hand, verbal comprehension is a key factor in understanding (and hence distinguishing among) items in personality questionnaires (Soto et al., 2008). It is perhaps for this reason that the findings of Study 2 suggest that both verbal and performal aspects of cognitive ability are associated with correlated change, with adolescents with lower cognitive abilities exhibiting more correlated change when compared to adolescents with higher cognitive abilities.

Although correlated change differs from trait differentiation, the present study and previous studies found similar associations of trait differentiation with age (Allik et al., 2004; Soto et al., 2008) and cognitive ability (Austin et al., 2002; Bowler et al., 2009; Di Blas & Carraro, 2011; Mottus et al., 2007; Toomela, 2003). The age differences in trait differentiation found in previous studies have also been attributed to changes in cognitive ability (Allik et al., 2004; Soto et al., 2008). Likewise, our findings on correlated change in Study 2 seem to suggest that the age differences we found in Study 1 may be at least partly attributable to age-related changes in cognitive ability. However, because we were unable to test the effects of age and cognitive ability in one and the same study, no definite conclusions can be drawn regarding the role of cognitive ability in the effect of age on correlated change.

Further findings suggest that age patterns in correlated change are unlikely to be completely attributable to developmental changes in cognitive ability. That is, there were particular age patterns in specific Big Five trait combinations that have previously been linked to broad mechanisms other than cognitive ability. Specifically, the findings in Study 1 suggest that correlated change between agreeableness, conscientiousness, and emotional stability was greater than correlated change among other trait pairs from age 25 to approximately age 45, and then again around age 65.

The period between age 25 and 45 overlaps largely with Erikson's (1950) original conceptualization of young adulthood as the period between ages 20 and 40. Young adulthood is the period in which individuals are most likely to transition into social roles of adult life, such as having a stable job and a stable family (Roberts et al., 2005). Around age 65, most individuals transition out of their job role in West-European countries because of retirement. According to the Social Investment Principle (SIP; Roberts et al., 2005), transitions into such adult social roles, especially if they lead to investment in these roles, may lead to increases in emotional stability, agreeableness, and conscientiousness. The same could be true for transitions out of these roles due to retirement. Because age-related relative increases in the magnitude of correlated changes between emotional stability, agreeableness, and conscientiousness seem to occur at ages at which investment and de-investment in adult social roles are most common, correlated change among these traits may be associated with change in the investment in social roles. Although patterns in the two processes seem similar, proposing linkages between the two is quite speculative. Therefore, a study directly examining the effects of changes in social investment on correlated change between emotional stability, agreeableness, and conscientiousness will be needed to uncover whether our speculative interpretation holds.

Changes in extraversion and openness (i.e., the trait-pair that has been associated with the dopaminergic system) were strongly associated with one another throughout the lifespan. Furthermore, correlated change between these two traits increased towards even higher levels in old age. The dopaminergic system is also known to change in the period from adulthood to old age (Weickert et al., 2007). Furthermore, Study 2 suggested that there was even stronger evidence for correlated change between extraversion and openness among individuals with relatively low cognitive abilities, whereas the dopaminergic system has been linked to cognitive ability in a similar way (Bolton et al., 2010). Thus, the associations of age and cognitive ability with correlated change that we found seem rather similar to associations of age and cognitive ability with the dopaminergic reported in previous studies. This could suggest that the dopaminergic system is causing correlated change between extraversion and openness which would, in turn, be in line with previous research linking these two traits to that system (DeYoung & Gray, 2009; DeYoung et al., 2002).

10.2. Strengths and limitations

The primary strength of the present research is its reliance on two studies of which each provides a unique piece to the puzzle of correlated change. That is, we were able to examine age effects in Study 1 and cognitive ability effects in Study 2. Including two studies further allowed us to establish correlated change as a replicable phenomenon across different samples. Furthermore, the sample employed in Study 1 was nationally representative, which contributes to the generalizability of our findings.

Furthermore, we controlled for cross-lagged effects to obtain the most accurate estimates of correlated change. This is important for an unambiguous interpretation of the results, because correlated change coefficients can be confounded with cross-lagged effects. Cross-lagged effects would, however, not indicate the operation of broad mechanisms of personality development that jointly affect different traits, but rather represent the effects of one trait on another, implying narrow-acting mechanisms of change.

Despite these strengths, several limitations need to be acknowledged. First, we could not simultaneously examine age effects and cognitive ability effects to assess theirrelative contributions. Because of this it remains, for example, unclear whether individual differences in cognitive ability fully explain age-related effects on correlated change. To better examine this issue, participants in large scale studies like Study 1 would all need to fill out the very same cognitive test in addition to the personality questionnaires they already completed. Raw scores instead of the usual standardized scores of cognitive ability could then be used alongside age as a predictor of correlated change in order to examine their unique effects.

Second, Study 1 may cover an impressive age range, but the youngest participants in this study were already 17 years old. Several studies showed that large increases in trait differentiation take place between age 12 and 18 (Allik et al., 2004; Soto et al., 2008). Although correlated change is different and independent from trait differentiation, the largest decreases in correlated change may also occur in that period. Related to this, Study 1 and 2 did not overlap in terms of age, making it somewhat unclear whether the effects of cognitive ability that were found in Study 2 would also apply to the age cohorts sampled in Study 1.

Third, age effects in correlated change were conflated by birth cohort. To be fully confident that age-related differences in correlated change are truly age-effects rather than birth-cohort effects, one should ideally follow the same individuals across substantive periods of time with multiple measurement occasions.

A related, fourth, important limitation was that there were only two waves of data available in both studies. A first reason to increase the number of measurement occasions is that estimates of change become increasingly more reliable when more waves of data are added (e.g., Willett, Singer, & Martin, 1998). That is, the odds that change coefficients are largely driven by measurement occasion-specific effects decrease considerably when more waves of data are added. Second, if three or more waves of data are included, latent growth models can be estimated in a Structural Equation Modeling (e.g., Duncan, Duncan, Stryker, Li, & Alpert, 1999) or a Multilevel Modeling (Hox, 2002) framework. Correlated change can then also be estimated by examining correlations between latent growth estimates (i.e., slopes) that are more reliable than the Time 2 residual correlations that we used in the present research. So far, only one study (Soto & John, 2012) has employed more than 2 (i.e., 5) measurement occasions. In that study, correlated change was examined using a multilevel approach. None of the change correlations was significant, but it should be noted that the sample they employed was relatively small and not necessarily representative. That is, they followed 125 women that graduated from college between 1958 and 1960. Thus, it is too early to draw firm conclusions regarding the extent to which the number of measurement occasions that are included may affect correlated change coefficients.

Fifth, the sample size of Study 2 was rather modest. As a result, statistical power issues caused us to choose for comparing individuals with average versus high IQ. In a larger sample with greater diversity in cognitive abilities we would have been able to provide a more detailed perspective on the associations between cognitive ability and correlated change.

10.3. Conclusion

The present research found consistent evidence for the existence of a modest amount of correlated change among personality traits. Overall, correlated change was relatively stable from adolescence through adulthood, but stronger in individuals aged 70 and older. Changes in cognitive ability likely partly, but by no means completely, explain these findings, as correlated change was stronger in adolescents with low cognitive ability than in adolescents with high cognitive ability. In addition, our results suggest that broad mechanisms other than cognitive ability (e.g., the dopaminergic system and investment in adult social roles) may play a role in producing correlated change. Thus, personality development appears to be at least partly driven by broad mechanisms affecting multiple traits in addition to narrowly operating mechanisms affecting single traits. The next challenge will be to ascertain what these broad mechanisms exactly constitute.

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