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Developmental Associations between Short-Term Variability and Long-Term Changes: Intraindividual Correlation of Positive and Negative Affect in Daily Life and Cognitive Aging

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Abstract

Conceptual notions and empirical evidence suggest that the intraindividual correlation (iCorr) of positive affect (PA) and negative affect (NA) is a meaningful characteristic of affective functioning. PA and NA are typically negatively correlated within-person. Previous research has found that the iCorr of PA and NA is relatively stable over time within individuals, that it differs across individuals, and that a less negative iCorr is associated with better resilience and less vulnerability. However, little is known about how the iCorr of PA and NA relates to cognitive aging. This project examined how the association between PA and NA in everyday life is associated with long-term cognitive aging trajectories. To do so, we linked micro-longitudinal data on PA and NA obtained on up to 33 occasions over six consecutive days with macro-longitudinal data on fluid and crystallized cognitive abilities obtained over 15 years from a subsample of Berlin Aging Study participants (N = 81, mean age at the micro-longitudinal study = 81 years, range 73–98; 41% women). Over and above age, gender, education, overall levels of PA and NA, and number of health conditions, a less negative iCorr of PA and NA was associated with lower levels of cognitive ability and steeper cognitive declines, particularly for fluency and knowledge abilities. We discuss possible mechanisms for this finding and argue that a less negative iCorr of PA and NA may be indicative of deficits in emotional integration that are tied to changes in crystallized aspects of cognitive abilities.

Keywords

longitudinal; cognitive aging; positive and negative affect; intraindividual correlation of positive and negative affect

It is well documented that many cognitive abilities typically decline in old age (e.g., Baltes, Staudinger, & Lindenberger, 1999; Schaie, 2005). Although positive affect and emotional

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well-being do not seem to show age-related decrements throughout middle and old adulthood (e.g., Carstensen, Pasupathi, Mayr, & Nesselroade, 2000), very old age and late-life are typically associated with declines in positive affect, emotional well-being, and life satisfaction (for overview, see Baltes & Smith, 2003; Gerstorf & Ram, 2013). Notably, linkages between affective functioning and long-term longitudinal changes in other core areas of functioning such as cognition are not yet well understood. The present study aims to fill this gap by examining how affective variability in daily life is associated with long-term cognitive change. In the present study, we use data from a 6-day micro-longitudinal module that was embedded within the Berlin Aging Study (BASE). This module, which included 30+ within-day assessments of positive affect (PA) and negative affect (NA) across 6 consecutive days, is used to examine links between the structure of momentary PA and NA and multiple aspects of cognitive aging assessed over 15 years as part of the larger BASE assessment battery. We will first introduce the literature on affective experiences in daily life, followed by different conceptualizations of iCorr of PA and NA to lay out our theoretical rationale and working model.

Major theories of affect propose that PA and NA represent two dimensions that are separable in experience (Cacioppo & Berntson, 1994; Thayer, 1989; Watson, 2000). Given that PA and NA are separable, they can, in principle, be experienced at the same time (Larsen & McGraw, 2011). Emotion theorists have proposed that daily affective experience is typically characterized by mixed affective states and that pure affective states are rare (Izard, 1977; Plutchik, 1980; Watson, 2000). Indeed, early studies of affect using experience sampling methods have shown that PA and NA co-occur in daily life (Diener & Emmons, 1985; Watson, 1988). Addressing mixed affective states with respect to individual differences, previous research has shown that people differ in the degree to which their PA and NA are coupled (or are independent) in daily life, day-to-day or moment-to-moment (e.g., Carstensen et al., 2000; Grühn, Lumley, Diehl, & Labouvie-Vief, 2013; Rafaeli, Rogers, & Revelle, 2007; Ram Conroy, Pincus, Hyde, & Molloy, 2012; Ready, Carvalho, & Weinberger, 2008).

Conceptual notions and empirical evidence both suggest that the intraindividual correlation (iCorr) of PA and NA is a meaningful quantification of individuals' everyday affective experiences (Carstensen et al., 2000; 2011; Ong & Bergeman, 2004). Research with samples of different age groups has found that the iCorr of PA and NA is relatively stable over time within individuals (i.e., is trait-like) and differs across individuals (Rafaeli et al., 2007; Hershfield, Scheibe, Sims, & Carstensen, 2013).

In brief, the iCorr across repeated self-reports of daily PA and NA has been interpreted as a marker of affect synchrony (Pitzer & Bergeman, 2014; Rafaeli et al., 2007), affect polarity (Ram et al., 2012), emotional complexity (e.g., Grühn et al., 2013; Ready, Akerstedt, & Mroczek, 2012), and poignancy (e.g., Carstensen et al., 2000; 2011). Generally, high positive iCorr of PA and NA indicates that PA and NA travel up and down together in the same directions (*synchrony*) and/or that PA and NA occur at the same time (mixed affect). An iCorr near 0 indicates that PA and NA travel independently (*asynchrony*, see descriptions in Pitzer & Bergeman, 2014), and may mix on some occasions. Negative iCorr indicates that PA and NA consistently travel in opposite directions (*desynchrony*) and do not mix. Previous studies have typically found that, on average, PA and NA were somewhat desynchronized (e.g., $r = -0.35$ for momentary affect, Carstensen et al., 2000; $r = -0.32$ to $r = -0.52$ for daily affect, Ready et al., 2008).

Antecedents and Consequents of the Intraindividual Correlation of PA and NA

Beyond a description of associations between PA and NA in daily life, which is an interesting phenomenon per se, researchers have started exploring potential antecedents and consequents by linking the iCorr of PA and NA to a variety of other between-person differences. For example, Ram and colleagues (2012) examined extraversion as a possible antecedent of the iCorr of PA and NA and argued that the iCorr of PA and NA would be more negative among more extraverted individuals as they might be more sensitive to positive daily events. This reasoning was supported by their findings that the iCorr of PA and NA was more negative among more extraverted individuals. Regarding the consequents of the iCorr of PA and NA, Hershfield and colleagues (2013) have argued that an affective experience characterized by a less negative iCorr of PA and NA could be indicative of "taking the good with the bad" and might help individuals deal with adversities, thus being beneficial in maintaining one's physical health. This reasoning was supported by their findings showing that individuals whose iCorr of PA and NA increased over time also tended to show attenuated declines in physical health.

Generally, it has often been argued that a less negative iCorr between PA and NA reflects flexibility in adequately responding to different contexts and a less negative iCorr has been assumed to be associated with more favorable developmental antecedents and outcomes. Examined in relation to other interindividual difference characteristics, studies have found that less negative iCorr of PA and NA (i.e., closer to zero or positive) is associated with less neuroticism (Ong & Bergeman, 2004; Ready et al., 2012), less daily stress (Ong & Bergeman, 2004), higher self-esteem (Bodner, Palgi, & Kaveh, 2013), better resilience (Ong & Bergeman, 2004), and better recovery from psychological symptoms in response to bereavement (Coifman, Bonanno, & Rafaeli, 2007). These findings are consistent with the idea that independently moving PA and NA is beneficial. However, there is also a somewhat smaller body of research that has not found such associations. For example, these same studies, as well as some others, did not find significant associations of the iCorr of PA and NA with physical health, life satisfaction, or depressive symptoms (Grühn et al., 2013; Ong & Bergeman, 2004). In sum, the literature to-date generally suggests that less negative iCorr between PA and NA is associated with "healthy" profiles, although these associations do not generalize across all variables.

In addition to the noted relations between individuals' trait-like characteristics (e.g., personality) and the iCorr between PA and NA, situational factors may also play a role. In particular, the iCorr of PA and NA might be indicative of how individuals regulate their emotions when faced with positive and negative daily events (see Palgi et al., 2014). It can be argued that in ordinary situations, individuals may benefit from independent PA and NA (as would be indicated by an iCorr of 0) because this may provide maximum information about their affective reactions to events (Zautra, Smith, Affleck, & Tennen, 2001). However, the independence of PA and NA would also result in uncertainty about affective responses, because experiences in one affective domain would not be indicative of experiences in another affective domain (Zautra et al., 2001). Thus, under stressful and challenging circumstances, individuals may tend to reduce this uncertainty by an affective experience characterized by a more negative iCorr of PA and NA. This interpretation is supported by evidence showing that the iCorr of PA and NA became increasingly negative during the experience of stress (Zautra, Berkhof, & Nicolson, 2002), pain (Zautra et al., 2001), or in close actual or perceived proximity of death (Palgi et al., 2014).

Notably, the studies thus far have only examined links between iCorr of PA and NA with psychosocial correlates (e.g., personality, self-esteem, and well-being). It remains an open question whether the correlation/independence of PA and NA is also linked to cognitive "health" or cognitive aging. Reviews on emotion-cognition links (Kryla-Lighthall & Mather, 2009; Mather, 2010) suggest that better cognitive abilities in old age are associated with better emotion regulation and higher subjective well-being. For example, older adults who had better strategic processing abilities were more successful in emotion regulation (see Kryla-Lighthall & Mather, 2009). Combining the findings that less negative (i.e., closer to zero or positive) iCorrs tend to be associated with "healthier" profiles (e.g., lower neuroticism, higher self-esteem) and that near-zero iCorrs are considered indicative of flexibility of affective response in different contexts, leads to the hypothesis that less negative iCorrs would also be associated with more favorable cognitive aging trajectories. That is, individuals with iCorrs of PA and NA closer to zero (or positive) are expected to exhibit more favorable trajectories of aging-related cognitive decline. In a similar vein, previous research (e.g., Zautra et al., 2002) suggests that a more negative iCorr could be indicative of high stress. Given the long-term effects of stress on cognition (Lupien, McEwen, Gunnar, & Heim, 2009), it can be expected that individuals with a less negative iCorr of PA and NA would show more favorable trajectories of cognitive change.

In contrast, it has also been argued that a less negative iCorr of PA and NA represents a lack of emotion integration capacity. For example, dynamic integration theory (DIT), which describes the dynamic relations between aspects of cognition and emotion across the lifespan (Labouvie-Vief & Marquez, 2004), suggests that, especially when cognitive decline becomes paramount, the ability of older adults to process and regulate emotional experiences may reach its limits (Labouvie-Vief, 2003). Specifically, DIT differentiates between automatic emotional processes and higher-order complex cognitive and executive processes (Labouvie-Vief, 2009). These latter higher-order cognitive processes are associated with higher cognitive-affective complexity, a construct that reflects the awareness of positive and negative emotional experiences and their representation in a cognitive-affective structure (Labouvie-Vief & Marquez, 2004). Well documented cognitive declines typically found in very old age (e.g., Baltes et al., 1999; Hülür, Infurna, Ram, & Gerstorf, 2013) might impair such higher-order processes, leading to less efficient affective processing, which then could result in less negative iCorr of PA and NA. From this perspective, individuals with a less negative iCorr of PA and NA would tend to show less favorable trajectories of cognitive change.

The Present Study

In the present study, we test whether or not the iCorr of PA and NA, as one aspect of individuals' daily affective functioning, is associated with long-term changes in cognitive functioning. Based on DIT assumptions, we hypothesized that a less negative iCorr of PA and NA would be associated with less favorable trajectories of cognitive aging. To test this hypothesis, we used longitudinal data from BASE. The majority of participants in BASE were already beyond their 60s and early 70s at Baseline and have been examined into very old age. Importantly, very old age is often characterized by substantial functional declines in both health and cognition (e.g., Baltes et al., 1999; Suzman, Manton, & Willis, 1992). Empirical evidence has shown that, on average, emotional well-being also deteriorates in very old age and late in life (Baltes & Smith, 2003; Gerstorf, Ram, Lindenberger, & Smith, 2013; Mroczek & Spiro, 2005; Palgi et al., 2010). For example, very old individuals in the BASE (aged 85 and older) showed lower levels of positive affect as compared to participants aged 70 to 85 years (Smith, 2001). Thus, very old age can be seen as a testing-the-limits situation where interindividual differences emerge or become more apparent and are thus easier to discern (see discussion in Gerstorf & Ram, 2012). As such, the final phase of life offers a unique opportunity to examine links between affective functioning and cognitive aging.

In the present study, we examine how specific processes manifesting on relatively fast time-scales are related to long-term developmental processes manifesting on relatively slow time scales (see Gerstorf, Hoppmann, & Ram, 2014; Nesselroade, 1991; Ram et al., 2014; Ram & Gerstorf, 2009; Röcke & Brose, 2013). Generally, linking across fast and slow time-scales is facilitated by multiple time-scale study designs wherein “bursts” of measurement, i.e., multiple repeated assessments that are obtained at relatively short intervals (e.g., hours, days, weeks), are embedded within longitudinal panel studies, where repeated assessments are obtained at relatively long intervals (e.g., monthly, yearly; see Nesselroade, 1991; Ram & Diehl, 2015; Ram, Gerstorf, Lindenberger, & Smith, 2011; Sliwinski, 2011). Here, our examination is facilitated by a micro-longitudinal “experience sampling” module that was embedded in the middle of the Berlin Aging Study's (BASE; Baltes & Meyer, 1999) bi-annual assessments of cognitive functioning. The “experience sampling” during a week of individuals' daily life provided for measurement of the moment-to-moment fluctuations in affect, and the bi-annual assessments of cognition provided for tracking of long-term changes in individuals' fluid and crystallized cognitive ability during old age.

To control for known individual differences in affect and cognitive ability, our models covaried for age, gender, education, overall (trait) levels of PA and NA, and number of health conditions. Based on previous findings from BASE (Lövden, Ghisletta, & Lindenberger, 2004), we expected that younger participants, individuals with more years of education and higher levels of PA and NA, and those with better health would show more favorable trajectories of cognitive aging. We examined whether the iCorr of PA and NA was independently associated with trajectories of cognitive change.

Method

We used 30+ occasion micro-longitudinal data obtained over 6 days and 5 occasion macro-longitudinal data obtained over 15 years from a subsample of BASE participants. Detailed descriptions of the macro-longitudinal and micro-longitudinal assessment procedures can be found in Baltes and Mayer (1999) and Hoppmann, Gerstorf, Smith and Klumb (2007), respectively. Select details relevant to the present study are given below.

Participants

Data were obtained from 81 participants (33 women, 41%) who volunteered, after completing the third measurement wave of the BASE, to participate in an additional time-sampling study. At the start of BASE (T1), these participants were between 70 and 93 years old (M = 76.7; SD = 4.97) and had obtained an average of 11.4 years of formal education (SD = 2.4). The average age at the micro-longitudinal module was 80.7 years (SD = 5.01; *range*=73–98). As expected for subsamples volunteering for intensive diary studies, the participants in the present study were among the upper quartiles of the larger BASE sample (N = 516), especially in terms of cognition (SD = +1.2), vision (SD = +1.0), and hearing (SD = +0.8; see Klumb & Baltes, 1999a).

Besides eight participants (9.9%) who were only followed longitudinally through their late 70s (between 75 to 79 years of age), the vast majority of these participants were followed through their 80s (n = 55; 67.9%) and into their 90s (n = 18; 22.2%). A dichotomous marker of probable dementia diagnosis was defined at each wave of the BASE (see Gerstorf, Herlitz, & Smith, 2006) based on the of age cohort-specific cutoffs of a dementia screening instrument (Short Mini Mental State Examination; Klein et al., 1985). The majority of participants of the micro-longitudinal study (n = 66; 81%) were classified as *not* having a probable dementia diagnosis throughout their participation in BASE; 15 participants were classified as having a probable dementia diagnosis at least once during their participation in BASE.

Procedure

Macro-longitudinal assessments—As part of the usual BASE protocol, participants completed a variety of questionnaire and performance measures at about 2- to 5-year intervals. The present analysis makes use of 5 repeated measures of cognitive ability obtained over about 15 years. The testing protocol was carried out by trained research assistants and medical personnel in individual, face-to-face sessions at the participant's place of residence. Each session required an average of 90 minutes. When necessary, the sessions were split into shorter units of assessment.

Micro-longitudinal module—Between 13 and 73 days after completing the third measurement wave of the BASE (T3), participants in the micro-longitudinal module were visited by a research assistant and provided instruction on use of a portable beeper and completion of a set of paper diaries where they would provide reports about their affective states and activities. On each of the following 6 days, the portable beeper prompted participants with an audio signal at five pseudo-random times that were adjusted to occur within the window framed by individuals' typical wake-up and falling-asleep times. The minimum time interval between two consecutive signals was set to 15 minutes, with the average tending to about 150 minutes (Klumb, 2001). On average, participants completed 87% of 30 possible diaries (5 occasions on each of 6 days).

Measures

Cognitive abilities—Fluid (perceptual speed and memory) and crystallized (knowledge and word fluency) abilities (Cattell, 1971) were assessed in the macro-longitudinal study using tasks administered on a Macintosh SE/30 computer equipped with a touch-sensitive screen (for details, see Lindenberger & Baltes, 1997). *Perceptual speed* was measured as a unit-weighted composite of the Digit-Letter Test and Identical Pictures; *Memory* by Memory for Text and a Paired-Associates Task; *Knowledge* by Spot-a-Word and a vocabulary test; and *Word fluency* by the Categories and Word Beginnings test. As well, a general intelligence composite was computed as the average of the four cognitive composites. All cognitive ability scores were scaled to a T-score metric (M = 50, SD = 10) using the T1 BASE sample (N = 516) as a reference. Reliability was within the normal range for tests of episodic memory for the Memory for Text (Cronbach's α = 0.57) and satisfactory for all other tests, ranging from α = 0.82 to 0.96 (see Lövden et al., 2004).

Positive and negative affect—Each diary in the micro-longitudinal module included eight affect adjectives that were rated on a 5-point scale (0 = no experience of the particular affect to 4 = very intense experience of the particular affect). Four adjectives were drawn from the Yesterday Interview (happy, relaxed, bored, lonely; Klumb & Baltes, 1999b), and four were drawn from the Positive-Affect–Negative-Affect Scales (interested, active, irritable, depressed; Watson, Clark, & Tellegen, 1988). Participants were asked to rate their current affective state during the activity they were engaged in when the beeper prompted them to fill out a questionnaire (e.g., "How bored were you during your activity?", translation of "Wie gelangweilt waren Sie während Ihrer Tätigkeit?"). Exploratory factor analyses indicated a robust two-factor structure with positive and negative adjectives loading almost exclusively on one or the other factor, independent of whether those factors were kept orthogonal or rotated to an oblique solution (r = −.28). *PA* was measured as the average of responses to the adjectives interested, active, happy, and relaxed (Cronbach's α = 0.78). *NA* was measured as the average of responses to the adjectives depressed, irritable, bored, and, lonely (Cronbach's α = 0.67). On average, participants provided ratings of their PA and NA on 20.90 occasions (SD = 8.23, *Range* = 2 – 33).

Covariates—Age, gender, years of formal education, number of moderate to severe health conditions that were diagnosed by a consensus conference of physicians at T1 (converted to a T score metric based on the whole BASE T1 sample, N = 516), and overall (trait) levels of PA and NA (computed as the within-person mean of PA and NA ratings across the repeated measures of affect) were used as covariates. Descriptive statistics and correlations for the constructs in the present study can be found in Table 1. It can be obtained that, for example, individuals with a higher (i.e., less negative) iCorr of PA and NA tended to have lower (trait) levels of PA (r = −0.25).

Data analysis

Intraindividual Correlation of Positive and Negative Affect—*iCorr of PA and NA* was computed using the PA and NA scores across the up to 33 repeated assessments (Carstensen et al., 2000; Rafaeli et al., 2007, Ram et al., 2012). For three participants who showed no variation of NA the iCorr of PA and NA was set to 0. Figure 1 illustrates ratings of daily PA and NA for two participants, one person with a slightly positive iCorr of PA and NA (upper Panel A; $r = .22$) and one person with a negative iCorr of PA and NA (lower Panel B; $r = -.66$) across all measurement occasions of the micro-longitudinal module. Figure 2 shows a histogram of iCorr of PA and NA. It can be obtained that for most individuals, the iCorr of PA and NA was negative ($M = -.29$; $Mdn = -.27$) and that the magnitude of the iCorr varied across individuals ($SD = .35$). A negative iCorr of PA and NA was the normative case, with only 13 of the 81 participants (16%) showing any hint of a positive iCorr. For convenient interpretation of regression parameters, iCorrs of PA and NA were z-standardized for further analyses.

Intraindividual correlation of positive and negative affect and cognitive aging —Associations between iCorr of PA and NA and cognitive aging were examined using conditional growth models. The models were specified to examine changes in cognition with respect to time in study,

$$cognition_{ti}=\beta_{0i}+\beta_{1i}(time_{ti})+\beta_{2i}(time^{2}{}_{ti})+e_{ti}, \quad (1)$$

where $cognition_{ti}$, person i's score for a particular cognitive ability at time t, is a function of a person-specific intercept parameter β_{0i}, a person-specific linear slope parameter β_{1i} that characterizes the rate of change per year in study (centered at 3.98 years, the average duration of BASE participation at the time of the micro-longitudinal module), a person-specific quadratic slope parameter, β_{2i}, and residual error, e_{ti}. Between-person differences in intercepts (β_{0i}) and linear (β_{1i}) and quadratic (β_{2i}) slopes were modeled as

$$\begin{aligned}\beta_{0i}=&\gamma_{00}+\gamma_{01}(iCorr\ of\ PA\ and\ NA_i)\\&+\gamma_{02}(age\ at\ the\ micro-longitudinal\ study_i)\\&+\gamma_{03}(gender_i)\\&+\gamma_{04}(education_i)\\&+\gamma_{05}(mean\ PA_i)\\&+\gamma_{06}(mean\ NA_i)\\&+\gamma_{07}(number\ of\ health\ conditions\ at\,T1_i)+\mathrm{u}_{1i},\end{aligned} \quad (2)$$

$$\begin{aligned}\beta_{1i}=&\gamma_{10}+\gamma_{11}(iCorr\ of\ PA\ and\ NA_i)\\&+\gamma_{12}(age\ at\ the\ micro-longitudinal\ study_i)\\&+\gamma_{13}(gender_i)\\&+\gamma_{14}(education_i)\\&+\gamma_{15}(mean\ PA_i)\\&+\gamma_{16}(mean\ NA_i)\\&+\gamma_{17}(number\ of\ health\ conditions\ at\ T1_i)+u_{1i},\end{aligned} \quad (3)$$

$$\beta_{2i}=\gamma_{20}, \quad (4)$$

with all of the person-level predictors centered so that γ_{00}, γ_{10}, and γ_{20} indicated the typical trajectory, and other parameters indicated differences in level of cognitive ability and rate of cognitive aging favoring individuals with a higher (i.e., less negative) iCorr of PA and NA, women, those with more education, higher mean ratings of PA and NA, and a higher number of physician-diagnosed health conditions at baseline. Residual between-person differences u_{0i}, and u_{1i} were assumed multivariate normally distributed, correlated with each other, and uncorrelated with the residual errors, e_{ti} (due to the small sample size, variance of u_{2i} was not modeled). Models were estimated with SAS Proc Mixed (Littell, Miliken, Stoup, & Wolfinger, 1996) with incomplete data treated as missing at random (Little & Rubin, 1987).

Results

Table 2 presents results from the conditional growth curve models used to examine associations between iCorr of PA and NA and long-term change in multiple cognitive abilities. Average level of cognitive abilities at the time of the micro-longitudinal study (γ_{00}) ranged from 54.66 (for knowledge) to 58.57 (for perceptual speed). The variance in average levels (σ^2_{u0}) was reliably different from 0 for each cognitive ability after accounting for time trends and covariates. The linear slope (γ_{10}) was negative for each cognitive ability, indicating typical cognitive decline with time. In line with previous work (Lövden et al., 2004), for the subsample of participants who took part in the micro-longitudinal module, verbal knowledge showed relatively less linear decline ($\gamma_{10} = -0.12$), and perceptual speed showed accelerated declines ($\gamma_{20} = -0.06$).

Of particular interest for our research question were the associations between iCorr of PA and NA and level and rates of change in cognitive abilities. Results revealed that individuals with less negative iCorrs of PA and NA showed lower levels of cognitive abilities at the time of the micro-longitudinal study. The effects were most pronounced for word fluency ($\gamma_{01} = -2.44$), knowledge ($\gamma_{01} = -1.63$), and the intelligence composite ($\gamma_{01} = -1.67$). Less negative iCorr of PA and NA was also associated with steeper declines, with the strongest associations found for knowledge ($\gamma_{11} = -0.13$) and the intelligence composite score ($\gamma_{11} = -0.14$). Although the estimates were larger for crystallized (fluency, knowledge) as compared to fluid (perceptual speed, episodic memory) abilities, we note that the confidence intervals of these parameters were overlapping. Figure 3 illustrates the differences in 15-year trajectories of word fluency (Panel A) and knowledge (Panel B) for three fictitious individuals with highly positive (r = 1) zero (r = 0), and highly negative (r = −1) iCorrs between PA and NA.

We conducted three sets of follow-up analyses: First, to examine the possibility that the association between iCorr of PA and NA and cognitive change was driven by dementia, we repeated our analyses, excluding the subsample of participants who were classified as likely to receive a formal dementia diagnosis at some point during their participation in BASE (n = 15). In the more homogenous, non-dementia sample (n = 66), less negative iCorr between PA and NA was associated with lower levels of cognitive abilities; and the associations with word fluency (γ_{01} = −3.85) and knowledge (γ_{01} = −2.31) were not reduced. Less negative iCorr between PA and NA was again associated with steeper cognitive declines, with the strongest associations again found for the intelligence composite score (γ_{11} = −0.14) and knowledge (γ_{11} = −0.12). Second, high variability in affect might be considered an indicator of random fluctuation and a potential confounding variable that may conceal true associations (see Grühn et al., 2013). Our data revealed that those with greater fluctuation in NA also tended to have a more negative iCorr between PA and NA (r = −0.23). To control for individual differences in fluctuations of NA, we conducted an analysis where the intraindividual standard deviation (iSD) of daily NA (M = 0.41; SD = 0.29) was included as a covariate. We again found a similar pattern of findings, where less negative iCorr of PA and NA related to lower levels and steeper declines of cognitive abilities. The strongest effects were found for level and declines of the intelligence composite score (γ_{01} = −1.78 and γ_{11} = −0.16, respectively), for level of fluency (γ_{01} = −2.75) and for changes in knowledge (γ_{01} = −0.16). Also, the same pattern of findings was found after excluding three participants with no NA variation. Third, we conducted a parallel analysis controlling for the iSD of PA (M = 0.55; SD = 0.21). Again, the findings showed a similar pattern, where less negative iCorr of PA and NA related to lower levels and steeper declines of cognitive abilities. We found strongest effects for level and declines of the intelligence composite score (γ_{01} = −1.65 and γ_{11} = −0.17, respectively), for level of fluency (γ_{01} = −2.36), and for changes in knowledge (γ_{01} = −0.15).

Discussion

Our goal in the present study was to extend previous evidence regarding associations between iCorr of PA and NA in daily life and “healthy” outcomes in the well-being and health domains, by examining the cognitive correlates of the iCorr of PA and NA. We used data collected from individuals in old and very old age, a “testing the limits” phase of the life span where individual differences become apparent or more pronounced (see Gerstorf & Ram, 2012; for discussion). Thus, these data offered a unique opportunity to examine associations between cognition and affect. We linked micro-longitudinal data on PA and NA obtained from a subsample of the BASE to macro-longitudinal data on cognitive functioning over 15 years. On average, the iCorr between PA and NA was modestly negative (r = −0.29). Importantly, there were also individual differences in the iCorr of PA and NA (SD = 0.35). Our findings revealed that less negative iCorr of PA and NA was associated with stronger cognitive decline trajectories, particularly for the crystallized abilities of fluency and knowledge.

A possible mechanism that could explain this finding revolves around deficits in emotional integration tied to declining crystallized abilities. Higher-order processes relating to emotional competencies have been found to draw more on acculturated (crystallized) knowledge of individuals than abstract (fluid) abilities (Labouvie-Vief & Diehl, 2000). Within the theoretical framework of the DIT (Labouvie-Vief, 2009), automatic affective processes are differentiated from complex cognitive and executive processes. These latter higher-order processes are necessary to recognize PA and NA as well as to integrate them into a complex cognitive-affective structure (Labouvie-Vief & Marquez, 2004). Such higher-order processes might become impaired with declining cognitive resources, which would then result in less efficient affective processing, and in less negative iCorr of PA and NA. The finding that associations of iCorr of PA and NA with cognition were more pronounced for higher-order verbal abilities of word fluency and knowledge offers further support for this interpretation because these crystallized abilities likely play a role in the semantic processing and integration of affect as opposed to abilities that can be considered a cognitive primitive such as perceptual speed, or other fluid abilities (Labouvie-Vief & Diehl, 2000). We note that it is not clear exactly how our measure, the iCorr of PA and NA, overlaps with the emotional disintegration and cognitive-affective complexity constructs described within the DIT framework given that emotional competencies as well as the complexity of affect structure have typically been assessed with narrative measures (e.g., Labouvie-Vief & Medler, 2002).

Taking a slightly different perspective, the iCorr of PA and NA can be considered with respect to diversity of emotional experience. A number of studies with younger adults have shown that experience of singular emotions, as opposed to heterogeneous emotions, is associated with better emotion regulation (Barrett, Gross, Conner, & Benvenuto, 2001), more efficient coping strategies (Tugade, Fredrickson, & Barrett, 2004), resilience against excessive alcohol use (Kashdan, Ferssizidis, Collins, & Muraven, 2010) and less aggressive tendencies (Pond et al., 2012). Similarly, analysis of a different subsample of BASE indicated that lower emotional diversity may be associated with more positive cognitive aging over the prior 15 years (Ram et al., 2011). Together with the results obtained here, these findings imply that individuals who are less likely to experience PA and NA at the same time (i.e., more negative iCorr of PA and NA) might be the ones who are more successful in choosing adequate emotion regulation strategies; and/or in communicating their emotions and thus facilitating the types of social support that help them maintain "health."

Limitations and Outlook

The BASE data collections were not designed to specifically test the mechanism and potential consequents described above. The design and placement of the micro-longitudinal module precluded examination of antecedent-consequent associations between iCorr of PA and NA and cognitive aging and other developmental outcomes because of the small number of macro-longitudinal measurements obtained prior to and after the micro-longitudinal module. Also, the relatively small sample size precluded examination of non-linear associations between iCorr of PA and NA and rate of cognitive aging. Furthermore, we note that the interdependence of PA and NA could alternatively be quantified using P-technique person-specific factor analytical methods (see Brose & Ram, 2012). Due to the relatively small number of micro-longitudinal observations available per participant (up to 33 with an average of 21) we were not able to perform such analyses. Future studies with integrated micro- and macro-longitudinal designs are needed to examine such relationships (see also Ram, Gerstorf, Lindenberger, & Smith, 2011).

A second limitation of the present study relates to the measure of PA and NA. Studies of iCorr of PA and NA so far have used varying sets of adjectives for the ratings of PA and NA. In future studies, consideration of specific items might offer further insight into the nature and correlates of iCorr of PA and NA, and into possible mechanisms responsible for these associations. The present study involved a range of affect adjectives, but not instantiations of distinct emotions such as happiness, fear, or anger. Future research should replicate and extend this by looking at a broader representation of these sub-facets in a larger sample. The meaning of affect ratings might also vary according to the time-scale of micro-longitudinal assessments. In the present study, participants were asked to rate their current affective state at 5 random occasions on each of the 6 days. iCorr of PA and NA based on daily ratings might measure a construct that to some extent differs from iCorr of PA and NA based on moment-to-moment or hourly ratings of affect. For example, when reporting affect over a shorter time frame (e.g., a few hours), individuals retrieve episodic knowledge. In contrast, over longer time frames (e.g., days or weeks), they rely on semantic knowledge (Robinson & Clore, 2002). Thus, iCorrs of PA and NA based on hourly vs. daily ratings might relate to cognition in different ways. Furthermore, future research needs to examine which specific affect dimensions may be driving the associations reported here. Our initial analyses showed that the iCorr of “happy” and “depressed” evinced the strongest associations with cognitive aging. However, this finding needs to be interpreted with caution and in light of reliability concerns when working with single items. It is also conceivable that the iCorr of PA and NA reflects response strategies of participants such as a less effortful response strategy (“satisficing”, see Krosnick, 1991). An argument could thus be made that individuals with less negative iCorrs are engaged in such strategies because their response patterns are more “random”. Future research needs to examine more fully, the cognitive sets and structures that are used during affective reporting.

Another limitation of the present study relates to sample selectivity. The participants of the present study were a positively select subsample of BASE participants (see Klumb & Baltes, 1999a). It would thus be instructive to examine whether the association between less negative iCorr of PA and NA and cognitive decline reported in the present study is generalizable to more heterogeneous groups of aging individuals. Also, our findings indicated that very few individuals (16% of all participants) exhibited a positive iCorr between PA and NA. As such, future research should carefully examine whether the observed empirical distribution of iCorr of PA and NA is a substantive phenomenon or due to the particular characteristics of our sample, such as the limited age-range or positive selection. We note that our indicator of (probable) dementia diagnosis at each wave is not optimized to detect very mild to moderate forms of dementia among very old adults (see Lindenberger & Baltes, 1997). Thus, our analyses cannot fully rule out the possibility of dementia as an explanation for the findings reported in the present study. However, we also note that our participants on average still performed on the various cognitive tests at T3 (which took place less than three months before the micro-longitudinal module) at 0.42 to 0.85 *SD* above the mean of the entire BASE sample at T1, suggesting that the prevalence of dementia was probably rather low among our participants. Similarly, our health measure was taken from the BASE Baseline, which took place 4 years prior to the micro-longitudinal module. Thus, although the physician ratings of Baseline health were objective, the health status of participants could have changed during this time period, and may have additional overlap with the iCorr of PA and NA. Further work is needed to identify and understand the range of individual difference variables that correlate with the iCorr of PA and NA.

Conclusions

The current study adds to previous work on iCorr of PA and NA by examining its cognitive correlates. Our findings showed that less negative iCorr of PA and NA relates to lower levels and steeper declines of cognitive abilities, particularly word fluency and knowledge. Cautiously, because they are the first results available, the findings suggest that less negative iCorr of PA and NA may be indicative of deficits in emotional integration tied to poor crystallized functioning. Further research is needed to replicate this finding and understand the antecedent/consequent relationships between iCorr of PA and NA and cognitive abilities, as well as antecedent/consequent relationships with other domains of functioning.

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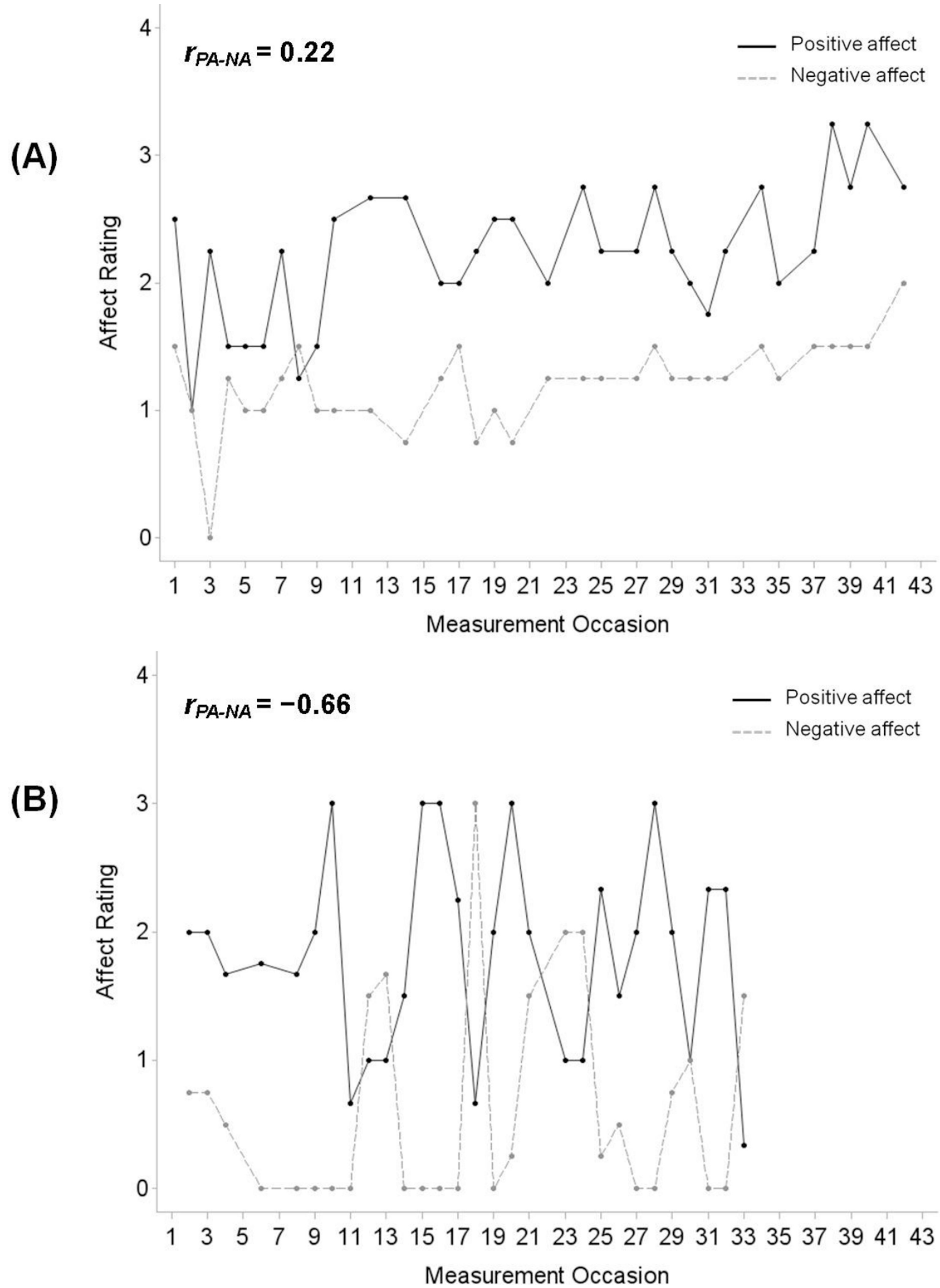

Figure 1.

Illustrating associations of iCorr of PA and NA with daily affect. Figures depict ratings of daily experiences of PA and NA for two participants with slightly positive (Panel A; r = 0.22) and negative (Panel B; r = −0.66) iCorrs of PA and NA across all measurement occasions of the micro-longitudinal study. Panel A: For the participant with a slightly positive iCorr of PA and NA, PA and NA were relatively independent, or on occasions when he/she reported PA, he/she also tended to report NA. Panel B: The participant with a negative iCorr of PA and NA tended to not report NA on occasions he/she experienced high PA (and vice versa).

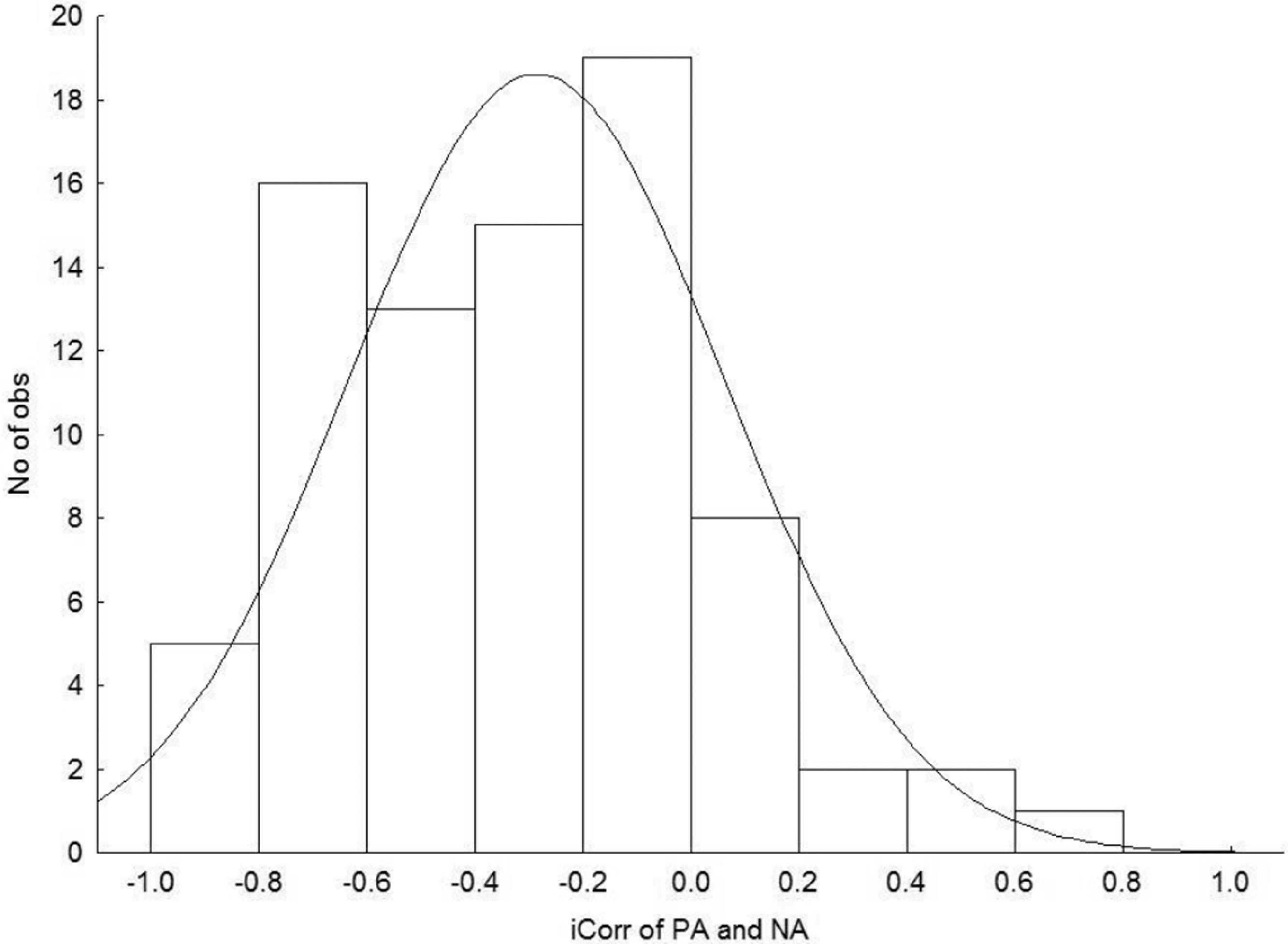

Figure 2.
Histogram of the iCorr of PA and NA. It can be obtained that a negative iCorr between PA and NA was the normative case.

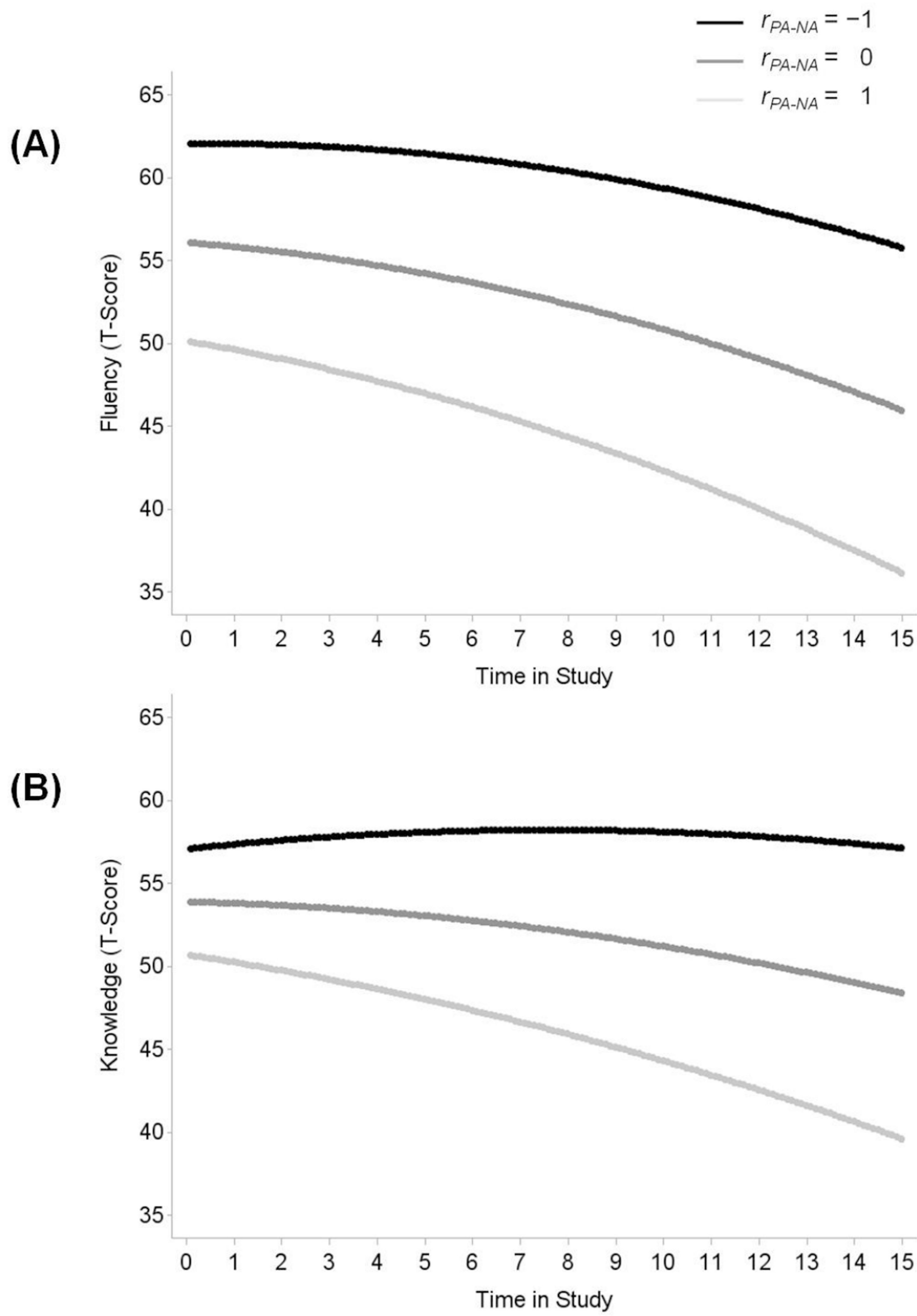

Figure 3.

Illustrating associations of iCorr of PA and NA with fluency (Panel A) and knowledge (Panel B) over the course of study participation, from 0 to 15 years. Figures depict predicted trajectories of change in fluency and knowledge for highly positive (*r* = 1, light grey lines), independent (*r* = 0, dark grey lines), and highly negative (*r* = −1, black lines) associations between PA and NA. Panel A: Participants with a highly negative iCorr of PA and NA exhibited higher levels of fluency relative to participants with less negative iCorrs. Panel B: Participants with a highly negative iCorr of PA and NA demonstrated higher levels of knowledge and also experienced less steep knowledge declines relative to participants with less negative iCorrs.

Table 1

Descriptive Statistics and Correlations among Constructs.

	M	*SD*	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) iCorr of PA and NA (−1 – +1)	−0.29	0.35	1						
(2) Age at the micro-longitudinal study	80.70	5.01	0.07	1					
(3) Gender (0=men; 1=women)	0.41	0.49	−0.20	0.09	1				
(4) Years of education (8 – 17)	11.42	2.42	−0.10	−0.11	−0.08	1			
(5) Mean PA (0 – 4)	2.73	0.75	−0.25*	−0.23*	−0.19	0.16	1		
(6) Mean NA (0 – 4)	0.47	0.49	0.02	0.33*	0.01	−0.08	−.27*	1	
(7) Number of health conditions at T1 (T-score)	46.00	8.73	0.02	0.04	0.04	−0.20[a]	−0.15	0.07	1

* $p < 0.05$,

[a] $p \le 0.07$

Table 2

Growth Curve Models of Cognitive Ability Composite Scores: The Role of the Intraindividual Correlation of Positive and Negative Affect and Covariates.

	Intelligence	Perceptual Speed	Episodic Memory	Knowledge	Fluency
Parameter	**Estimate (SE)**	**Estimate (SE)**	**Estimate (SE)**	**Estimate (SE)**	**Estimate (SE)**
Fixed effects					
Intercept[a], γ_{00}	57.54* (0.72)	58.57* (0.58)	55.52* (0.90)	54.66* (0.83)	56.75* (0.89)
Linear slope, γ_{10}	−0.36* (0.08)	−0.33* (0.10)	−0.38* (0.12)	−0.12 (0.08)	−0.39* (0.12)
Quadratic slope, γ_{20}	−0.04* (0.01)	−0.06* (0.01)	0.00 (0.02)	−0.02 (0.01)	−0.03 (0.02)
iCorr of PA and NA, γ_{01}	**−1.67* (0.77)**	**−0.45 (0.60)**	**−1.14 (0.96)**	**−1.63[b] (0.89)**	**−2.44* (0.94)**
Age, γ_{02}	−0.04 (0.15)	−0.25[b] (0.12)	−0.02 (0.19)	0.13 (0.18)	0.02 (0.19)
Gender, γ_{03}	2.50 (1.52)	2.31[b] (1.20)	4.73* (1.90)	−1.30 (1.76)	2.69 (1.86)
Education (in years), γ_{04}	0.55 (0.31)	0.45[b] (0.24)	0.37 (0.38)	0.76* (0.35)	0.28 (0.37)
Mean PA, γ_{05}	1.47 (1.07)	1.44 (0.84)	1.53 (1.33)	−0.52 (1.24)	2.49[b] (1.30)
Mean NA, γ_{06}	−3.22* (1.60)	−0.63 (1.27)	−4.22* (2.00)	−5.08* (1.85)	−1.31 (1.96)
Number of health conditions at T1, γ_{07}	−0.12 (0.08)	−0.17* (0.07)	0.03 (0.11)	−0.03 (0.10)	−0.24* (0.10)
iCorr of PA and NA × Linear Slope, γ_{11}	**−0.14 (0.09)**	**−0.10 (0.11)**	**−0.11 (0.12)**	**−0.13[b] (0.07)**	**−0.09 (0.11)**
Age × Linear Slope, γ_{12}	−0.01 (0.02)	−0.02 (0.02)	0.00 (0.03)	−0.02 (0.02)	0.00 (0.03)
Gender × Linear Slope, γ_{13}	0.00 (0.17)	0.07 (0.20)	−0.20 (0.23)	0.07 (0.14)	−0.02 (0.21)
Education × Linear Slope, γ_{14}	0.01 (0.04)	−0.02 (0.04)	0.03 (0.05)	−0.01 (0.03)	0.00 (0.04)
Mean PA × Linear Slope, γ_{15}	0.05 (0.12)	0.12 (0.15)	−0.07 (0.17)	0.11 (0.10)	0.00 (0.15)
Mean NA × Linear Slope, γ_{16}	0.09 (0.19)	0.35 (0.24)	−0.02 (0.27)	−0.43* (0.17)	0.32 (0.26)
Number of health conditions at T1 × Linear Slope, γ_{17}	0.00 (0.01)	−0.01 (0.01)	0.01 (0.01)	−0.01 (0.01)	0.00 (0.01)
Random effects					
Variance intercept, σ^2_{u0}	37.17* (6.30)	19.82* (4.05)	54.80* (9.76)	49.38* (8.47)	50.35* (9.33)
Variance linear slope, σ^2_{u1}	0.22* (0.08)	0.30* (0.15)	0.32* (0.14)	0.02 (0.05)	0.07 (0.13)
Covariance intercept, slope, σ_{u0u1}	0.37 (0.47)	0.28 (0.51)	−0.43 (0.81)	0.21 (0.46)	1.10 (0.70)

	Intelligence	Perceptual Speed	Episodic Memory	Knowledge	Fluency
Parameter	**Estimate (SE)**	**Estimate (SE)**	**Estimate (SE)**	**Estimate (SE)**	**Estimate (SE)**
Residual variance, σ^2_e	8.13* (1.01)	13.95* (1.92)	22.05* (2.64)	13.21* (1.59)	28.27* (3.44)
Pseudo R^2	46.1 %	41.1 %	28.1 %	11.0 %	18.6 %
−2LL	1,668	1,729	1,884	1,737	1,900

Note. N = 81. Scores standardized to a T metric (M = 50, SD = 10) based on cross-sectional data of the T1 BASE sample (N = 516). Unstandardized estimates and standard errors are presented. Boldface type highlights the associations of the iCorr of PA and NA with cognitive trajectories. iCorr of PA and NA was z-standardized. All other covariates were effect coded/centered. Parameter estimates indicate the average trajectory and the extent of differences of a particular covariate. Positive parameters indicate differences favoring participants with less negative iCorr of PA and NA, older participants, women, participants with higher education, participants with higher overall levels of PA and NA, and participants with a higher number of physician-diagnosed health conditions at T1. 2LL = 2 log likelihood, a relative model fit statistic.

[a]Intercept is centered at 3.98 years, the average duration of study participation at the time of the micro-longitudinal module.

[b]$p \leq 0.07$,

*$p < .05$.