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Examining processing speed as a predictor of subjective well-being across age and time in the German Aging Survey

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Abstract

The purpose of the current study was to examine the associations between cognition, measured via the Digit Symbol Substitution Task, and subjective well-being (measured using the Satisfaction with Life Scale and the Positive and Negative Affect scale) in a community-based sample of middle-aged and older adults. Specifically, we examined both the cross-sectional and the longitudinal relationships between processing speed and subjective well-being. Data are from participants between 40–85 years-old (at baseline) who participated in the German Aging Survey across four waves. Results showed that processing speed was a weak but consistent predictor of positive affect, while age was associated with decreases in negative affect and positive affect, and increases in life satisfaction cross-sectionally. Conversely, cross-lagged panel analyses showed that the temporal relationship between processing speed and positive affect was close to zero, and non-significant. The results of this study shed additional light on the relationship between subjective well-being and cognition.

Keywords

Subjective well-being; positive affect; processing speed; digit symbol substitution task; German Aging Survey

Subjective well-being is a three-dimensional construct thought to comprise a cognitive-judgmental component (often assessed with the Satisfaction with Life Scale; SWLS; Diener, Emmons, Larsen, & Griffin, 1985), and affective components corresponding to positive and negative mood. High levels of subjective well-being have been considered a hallmark of successful aging (e.g., Rowe & Kahn, 1997, 1998). Age is associated with declines in physical health and cognition, as well as an increase in the loss of loved ones. Yet despite these age-related losses, increased age is associated with stable, or increased, subjective well-being. This finding has been labeled a paradox (e.g., Braun, Schmukle, & Kunzmann, 2017; Gana, Bailly, Saada, Joulain, & Alaphilippe, 2013; Hansen & Slagsvold, 2012; Isaacowitz & Smith, 2003; Mroczek & Kolarz, 1998). The paradoxical relationship between age and well-being is noteworthy because well-being is associated with a multitude of

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positive outcomes, including better mental and physical health (e.g., Lyubomirsky, King, & Diener, 2005).

One framework that has been used to understand the paradoxical relationship between age and subjective well-being is the socioemotional selectivity theory (Carstensen & Mikels, 2005), which suggests that increased age is associated with a shift in motivation, likely due to a change in time perspective that accompanies age. Namely, increased age is associated with an awareness of limited time. Increased age is therefore associated with the motivation to enhance well-being via maximizing positive affect and minimizing negative affect.

Alternatively, Frijters and Beaton (2012) interpret this paradoxical relationship as resulting from two sources of selectivity in participants. First, it may be that individuals who are already happy are more likely to experience happiness-increasing events in middle-age (e.g., marriage, promotions at work), resulting in the appearance that well-being increases after middle-age. Second, there may be unobserved heterogeneity between participants due to willingness of adults in each age range to participate in studies of well-being. They suggest that samples of older adults may unintentionally exclude the least happy older adults whose declining health prevents them from participating. Similarly, middle-age adults who are happiest may be too busy to participate in studies, therefore middle-age adults who participate may be less happy than their peers, resulting in the appearance of a U-shaped relationships between age and well-being.

Other research suggests that this paradox may be moderated by contextual variables that influence subjective well-being. There is evidence that a country's Gross Domestic Product affects older adults' well-being more strongly than younger and middle-age adults' well-being (Swift et al., 2014). Societal attitudes towards aging may also influence well-being, as perceived age discrimination has been shown to negatively impact well-being in adults 65 and older (Garstka, Schmitt, Branscombe, & Hummert, 2004). Individual variables such as income, gender, marital status, employment, and education (Blanchflower & Oswald, 2008; Frijters & Beaton, 2012; Hansen & Slagsvold, 2012) may also moderate the relationship between age and subjective well-being.

The separate components of subjective well-being appear to be differentially related to age. Positive affect (PA) or the "experience[s] of positive emotions such as joy, happiness, excitement, and pride" (Siedlecki, Donnay, & Paggi, 2012, p. 144) has been studied throughout the lifespan using longitudinal and cross-sectional methods. Several studies of older adults have found that PA declines with age (Ferring & Filipp, 1995; Smith & Baltes, 1993). Furthermore, in a cross-sectional study comprising participants aged 19 to 92 years, Rossi and Rossi (1990) found that age was associated with decreases in PA.

Negative affect (NA), or the experience of "negative emotions such as anger, disgust, shame, and anxiety" (Siedlecki et al., 2012, p. 144) has also been shown to decline with age. In their cross-sectional study, Rossi and Rossi (1990) found that, similar to positive affect, negative affect also declined with age, although negative affect declined more quickly than positive affect. These findings suggest that overall, as age increases, people feel both positive and negative emotions less often.

Life satisfaction (LS) is known to be partially influenced by NA and PA (e.g., Diener, Suh, Lucas, & Smith, 1999), however it is also a distinct component of subjective well-being. Baird, Lucas, and Donnellan (2010) found that LS is relatively stable throughout the lifespan, only declining in old age. Using both cross-sectional and longitudinal methods to assess two large, nationally representative datasets, they found that LS remains steady until 70 years of age, only after which it begins to decline (Baird et al., 2010). However, participants aged 45 to 89 in another study reported no significant differences in ratings of LS (Hamarat, Thompson, Steele, Matheny, & Simons, 2002). In a cross-sectional study examining participants between the ages of 18–88 years, Siedlecki et al. (2012) found that age was positively correlated with LS ($r = 0.22$). Stone, Schwartz, Broderick, and Deaton (2010) operationalized LS (which they labeled Global Well-Being) by asking participants to “Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. The top of the ladder represents the best possible life for you, and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time?” (p. 9989). In their sample of over 300,000 individuals, they found that across the lifespan, LS has a U-shaped relationship with age such that LS is high among young adults, lowest in middle-aged adults, and high again in older adults, increasing steadily after age 54 (Stone et al., 2010). Overall, the findings regarding the relationship between age and LS are mixed.

Predictors of subjective well-being

Several factors have been associated with aspects of subjective well-being, including health (e.g., Ngamaba, Panagioti, & Armitage, 2017), personality (e.g., Diener & Lucas, 1999; Steel, Schmidt, & Shultz, 2008), and social support (e.g., Siedlecki, Salthouse, Oishi, & Jeswani, 2013). Of particular interest in this study is cognitive functioning, which has also been linked to subjective well-being. Isaacowitz and Smith (2003) found that general intelligence was a significant unique predictor of increased PA and increased NA in a sample of adults between the ages of 70 and 105, after controlling for personality and contextual variables. Similarly, Kunzmann (2008) found that performance on a variety of cognitive tasks measuring perceptual speed, memory, knowledge, and fluency was positively related to PA and NA in a sample of adults aged 70–103, after controlling for self-rated mental fitness. A four-year follow up of this sample indicated that performance on cognitive measures at time 1 was significantly related to changes in PA, but not NA, across four-years (Kunzmann, 2008). Jones, Rapport, Hanks, Lichtenberg, and Telment (2003) found an association between better cognitive performance (measured by a composite of several cognitive variables) and LS and PA in a sample of adults between 65–89 years of age (but no relationship was found between cognitive functioning and NA). Braun et al. (2017) found that self-rated cognitive ability predicted subjective well-being in both middle-aged ($M_{age} = 43.70$) and older ($M_{age} = 62.47$) adults, while objective measures of cognition predicted well-being only in the older adult group.

Processing speed appears to have a particularly strong relationship with well-being. Enkvist, Ekström, and Elmståhl (2013) found that from a set of six cognitive domains, processing speed and spatial abilities were the strongest predictors of life satisfaction three years later in a sample of individuals between the ages of 78–98 (“the oldest-old”), and these relationships

remained significant after statistically controlling for sex, age, education, functional capacity, and depressed mood.

Furthermore, Wolinsky et al. (2009) reported on the effects of the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) randomized controlled trial in which individuals 65 years and older were randomized to a cognitive intervention targeting memory, reasoning, or processing speed, or to a no-contact control group. Participants in the processing speed training group had a 30% lower risk of developing clinically relevant increases in depressive symptoms, as compared to the control group, at both a 1-year and 5-year follow-up. There were no differences among the control, memory, and reasoning groups.

There is also evidence that greater levels of well-being in older adults over the age of 70 years may be associated with slower declines in perceptual speed (Gerstorf, Lovden, Rocke, Smith, & Lindenberger, 2007), providing evidence that the relationship between processing speed and subjective well-being may be bidirectional.

Explanations for the cognition-subjective well-being link

There are several potential explanations for the cognition-subjective well-being link. For example, Jones et al. (2003) speculated that higher cognitive functioning may be associated with the ability to appreciate “subtle positive aspects of living” (p. 14) or may be associated with the ability to better use resources in order to enhance well-being. Similarly, Isaacowitz and Smith (2003) suggest that higher cognitive functioning may be associated with greater well-being because it “allows individuals to stay more engaged with life”, and this increased engagement, in turn, is associated with “greater enjoyment” (p. 150).

Wolinsky et al. (2009) proposed two potential classes of explanations (indirect and direct) for the link between the processing speed intervention and reduced severity of clinical meaningful depressive symptoms. The indirect explanation posits that processing speed training directly affects a behavior (such as driving behaviors or instrumental activities of daily living) that then impacts depressive symptoms. The direct explanation includes mechanisms that directly influence mood through processing speed training, such as the “enhancement of neuromodulatory system through intensive activation of attentional and reward systems” (p. 471).

Enkvist et al. (2013) speculate that processing speed is related to LS because processing speed may be associated with the ability to participate in both social and societal activities, such as driving and learning. Furthermore, Stawski, Almeida, Lachman, Tun, and Rosnick (2010) examined the influence of fluid ability (which is strongly related to processing speed) on well-being in a diary study in which participants from Midlife in the United States Survey (MIDUS) reported their mood and daily stressors over a period of eight days. For some stressors, participants with higher levels of fluid ability reported smaller increases in stress-related negative mood, and smaller stress-related decreases in positive mood. This suggests that individuals with higher levels of fluid ability may exhibit more emotional resilience in the face of daily stress.

Value-as-a-moderator model

The value-as-a-moderator model posits that individual differences in subjective well-being may be influenced by the values that one holds and the degree to which one feels that their current life corresponds with these values. Specifically, it suggests that subjective well-being is positively correlated with engagement in value-congruent activities, and that these value-congruent activities have a stronger impact on subjective well-being than non-value-congruent activities (Oishi, Diener, Suh, & Lucas, 1999). These values can come from a variety of sources. For example, social expectations, culture, and personality are a few factors that may contribute to the development of individual values.

Research on the value-as-a-moderator model has found that culture and a country's economy both shape the values that affect subjective well-being (Oishi, Diener, Lucas, & Suh, 1998). In addition to varying across culture and economy, it has been suggested that values vary in importance based on life stage. For example, values that are important in childhood (e.g., making new friends) may become less important through adulthood, when new values are introduced (e.g., being a nurturing parent; Cantor & Sanderson, 1999).

Considering the cultural and developmental variations in values, the value-as-a-moderator model is a part of a comprehensive understanding of the factors that moderate LS. Prior research has found that age may moderate the relationship between cognition and LS. For example, Siedlecki, Tucker-Drob, Oishi, and Salthouse (2008) found that fluid ability predicted LS in young and middle-aged adults (between the ages of 18 and 59) but was not a significant predictor of life satisfaction, after controlling for self-rated health and NA, in older adults (between the ages of 60 and 94). Siedlecki and colleagues speculated that younger and middle-aged adults may value fluid ability to a higher degree as compared to older adults, who are more likely to be out of the work force. Thus, age will be examined as a moderator of the relationship between processing speed and subjective well-being in the current study.

Current study

The purpose of the current study was to further examine the relationship between subjective well-being and processing speed in a community-based longitudinal study. Data from the German Aging Survey were utilized to examine the relationship between cognition (operationalized as performance on the digit symbol task, a measure of processing speed) and subjective well-being. Provided by the Research Data Centre of the German Centre of Gerontology, the German Aging Survey (funded by the Federal Ministry for Family Affairs, Senior Citizens, Women and Youth) is an ongoing, population-based survey of individuals residing in Germany whose ages range from approximately 40 to 85 years at baseline. The survey currently includes five waves of data, first collected in 1996, then subsequently in 2002, 2008, 2011, and 2014. Participants completed face-to-face interviews and self-report questionnaires assessing various topics, such as health status, psychological well-being, social participation, family relations, and financial and housing situations. We were interested in examining both the cross-sectional and the longitudinal relationships between processing speed and subjective well-being. Thus, the first goal of the study was to examine

whether digit symbol performance predicts different aspects of subjective well-being across age cross-sectionally. The second goal was to examine whether age moderated the relationship between digit symbol performance and subjective well-being. The third goal of the study was to use cross-lagged panel analysis to examine the longitudinal relationships between processing speed and subjective well-being to assess whether subjective well-being or digit symbol performance is a stronger temporal predictor of the other.

Methods

Sample characteristics

Participants were recruited for the German Aging Survey through national probability sampling with stratified sampling by age, gender, and residential location in Germany. According to the Research Data Centre of the German Centre of Gerontology, in 1996 (Wave 1), there were 4,838 respondents from the birth cohort 1911–1956. In 2002 (Wave 2), data were collected from 1,524 of the Wave 1 participants in addition to 3,084 new individuals from the same regions as in Wave 1 from the birth cohort 1917–1962. In Wave 2, 586 non-German nationals from the birth cohort 1917–1962 were also surveyed via random sampling from the same geographical locations as Wave 1. In 2008 (Wave 3), 993 Wave 1 participants, 1,000 Wave 2 participants, and 6,205 new individuals from birth cohort 1923–1968 were surveyed. In 2011 (Wave 4), 1,040 Wave 1 participants, 957 Wave 2 participants, and 2,858 Wave 3 participants were surveyed. In 2014 (Wave 5), 887 Wave 1 participants, 866 Wave 2 participants, 2,569 Wave 3 participants, and 6,002 new individuals from birth cohort 1929–1974 were surveyed. In the current study, only individuals with scores on the digit symbol task were included in the analyses for each time point ($N = 3,724$ for 2002; $N = 6,145$ for 2008; $N = 4,121$ for 2011; $N = 8,174$ for 2014; see Table 1 for sample characteristics). Data from 1996 were excluded from the present analyses because the digit symbol task was not administered.

The average response rate for the waves in which new baseline samples were collected after 1996 (i.e., 2002, 2008, 2014) was 31.4% (Klaus et al., 2017). Although the response rates are low across the waves, response rates are comparable to other studies in Germany (Klaus et al., 2017; Romswinkel, König, & Hajek, 2018). According to Klaus and colleagues (2017), cross-sectionally, response rates tend to be systematically lower in larger cities, among women, and among individuals whose ages range from 40 to 54 and 70 to 85 years. In terms of retention rates of panel participants, 18.3% of 1996 panel participants, 21.8% of 2002 panel participants, and 41.4% of 2008 panel participants completed the interview in 2014 (Klaus et al., 2017). Similarly, longitudinally, sample selectivity is also observed. Those who are older, in worse health, have lower socioeconomic status (i.e., less education and lower incomes), and have a smaller social network tended to drop out of the study compared to those who stayed in the study. This suggests that those who are healthier and better functioning psychosocially are overrepresented over time (Klaus et al., 2017).

Subjective well-being

Life satisfaction.—Life satisfaction was measured by the Satisfaction with Life Scale (SWLS; Diener et al., 1985). The SWLS is a five-item measure in which participants

evaluate the concordance/discordance of their current life to their standards for life on a 5-point Likert scale. Scores can range from 5 to 35, with a score of 20 being the “neutral” point (Pavot & Diener, 1993). Diener and colleagues (1985) reported a test-retest stability coefficient of .82 over a two-month period, providing evidence that the measure provides a stable assessment of LS.

Positive and Negative Affect.—The Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) comprises 20 adjectives (10 representing PA and 10 representing NA). In the German Aging Survey, participants were asked to indicate to what extent they had felt a certain way during the past few months on a 5-point Likert scale (1 = very slightly or not at all, 5 = extremely). Participants were instructed that if they were unsure about a particular feeling, to choose the answer that most closely described how often they had felt that way. The PANAS has been shown to be internally consistent (Cronbach’s α range from .86 to .90 for PA scale and .84 to .87 for NA scale) and temporally stable (range from .47 to .68 for PA scale and from .39 to .71 for NA scale) over an 8-week test-retest interval (Watson et al., 1988). This test-retest stability suggests that although affect is generally thought to be a temporary mood state, it does have some relationship to one’s overall disposition.

PA and NA were represented by latent constructs in the analyses. Parcels have been shown to yield higher reliability (e.g., Kishton & Widaman, 1994), and higher communalities (e.g., Little, Cunningham, Shahar, & Widman, 2002). Thus, to reduce the number of indicators for the constructs, item parceling was used. Because the PA and the NA constructs were designed to be unidimensional, five parcels were created from the 10 PA and the 10 NA items by randomly pairing two items together and calculating the mean.

Processing speed

The Digit Symbol Substitution Test (Tewes, 1994; Wechsler, 1955) requires participants to write geometric symbols that correspond to numbers 1 to 9 based on a key provided at the top of the page as quickly as possible within 90 seconds. Higher scores indicate faster speed. In the German Aging Survey, participants were given seven examples to try with the interviewer for practice, and once these were completed, participants began the timed task. The number of correct responses ranged from 1 to 92, 2 to 92, 3 to 92, 1 to 92, for the 2002, 2008, 2011, and 2014 waves, respectively.

Covariates

As described above, age has been shown to be related to SWB. In addition, health has consistently been shown to have a robust relationship with subjective well-being (see a recent meta-analysis by Ngamaba et al., 2017). Health was assessed with a single self-rated item that asked “How would you rate your present state of health?” on 5-point Likert scale (1 = very good to 5 = very bad). Subjective health has been shown to correlate with objective measures of health (e.g., Jylha, 2009; Pinquart, 2001). Gender, loneliness, depression, marital status, and income were also included as covariates due to their established relationships with measures of SWB. Loneliness was assessed with the 6-Item Scale for Loneliness (De Jong Gierveld & Van Tilburg, 2006). Depression was assessed with the

German short version of CES-D-Scale (Hautzinger & Bailer, 1993). Marital status was dichotomized into “married, living together with spouse” and “other”. Income was the monthly net household income.

Analyses

Structural equation modeling was performed using AMOS 24.0 (Arbuckle, 2014). Several fit indices were inspected to evaluate model fit, including chi-square, chi-square ratio (X^2/df), and the root-mean-square error of approximation (RMSEA), in which values closer to zero indicate better fit. In addition, the comparative fit index (CFI), in which values greater than .95 indicate a good fit (Hu & Bentler, 1999), was also evaluated. A p value of .01 was used for all analyses, and full information maximum likelihood estimation was used to deal with missing data.

Cross-lagged panel analysis

Cross-lagged panel analyses typically involve four models (e.g., Martens & Haase, 2006). These models include: 1) a baseline model comprising autoregressive effects (e.g., digit symbol performance at time 1 predicts digit symbol performance at time 2, subjective well-being at time 1 predicts subjective well-being at time 2, etc.), as well as correlated disturbance terms between each variable at corresponding time points, 2) a model that includes autoregressive effects and also one variable (e.g., digit symbol performance) predicting the other variable over time (e.g., subjective well-being), 3) a model with the autoregressive effects and the alternate order of prediction (i.e., subjective well-being predicting digit symbol performance at later time points), and 4) a fully cross-lagged model including autoregressive effects and each variable predicting the other variable at the later time points.

Results

The zero-order correlations among LS, NA, PA, digit symbol performance, age, and other covariates are presented in Table 2 for the most recent wave of data (2014). Of note, age is significantly negatively associated with positive affect ($r = -0.11$) and negative affect ($r = -0.17$). In addition, the LS variable was coded such that lower numbers indicate higher levels of life satisfaction. Thus, increased age is significantly associated with increased ratings of life satisfaction ($r = -0.11$).

Cross-sectional analyses

Before examining predictors of subjective well-being, the fit of a three-factor model comprising LS, PA, and NA was examined across each wave of data. Although chi-square values were large due to the large sample sizes, CFI and RMSEA values indicate that the three-factor model was an excellent fit to the data in each wave: 2002 ($X^2(87) = 1091.56$; CFI = 0.959, RMSEA = 0.056), 2008 ($X^2(87) = 1851.47$; CFI = 0.977; RMSEA = 0.057), 2011 ($X^2(87) = 1118.09$; CFI = 0.958; RMSEA = 0.054), and 2014 ($X^2(87) = 2041.70$; CFI = 0.959, RMSEA = 0.052).

Structural equation modeling was used to examine the predictive validity of performance on the digit symbol task on each component of subjective well-being. Separate cross-sectional models were run for each wave of data. Gender, age, self-rated health, loneliness, depression, marital status, and income were included in the models as covariates. To evaluate potential moderating effects of age, models were compared across middle-aged (40–64 years of age) and older adults (over 65 years of age). See Figure 1 for a depiction of the model.

When examining the model depicted in Figure 1 across the different waves, several patterns emerge (see Table 3). First, digit symbol has the strongest relationship to positive affect (standardized coefficients are 0.11*, 0.01, 0.12*, and 0.05*) across the four waves; faster processing speed is associated with higher levels of positive affect. This relationship was significant for every wave except 2008. The relationship of digit symbol to life satisfaction (–0.02 0.05*, 0.03, 0.01) and negative affect (0.03, –0.01, –0.01, –0.02) is weaker and generally not significant across each wave. Also of note, the relationship between self-rated health and components of subjective well-being are robust and consistent across the waves such that better health is associated with higher ratings of LS and PA, and lower ratings of NA. In addition, gender is generally weakly and non-significantly related to life satisfaction and positive affect. However, gender is generally consistently significantly related to negative affect such that men report less negative affect. Age is significantly consistently negatively related to LS, PA, and NA. Lower scores on the LS variable indicate higher levels of LS, thus increased age was associated with increased ratings of LS. Increased age is also consistently negatively associated with lower levels of NA and PA. Loneliness has large and consistent relationships with components of SWB across the waves. Depression is also consistently related to SWB, with a particularly strong relationship with NA. Income is most strongly related to life satisfaction. In general, marital status has weak relationships with components of SWB.

Age moderation analyses

For each wave, the sample was divided into middle-aged (40–64 years of age) and older age groups (65+) to examine whether age moderated the relationship between digit symbol and subjective well-being. As shown in Table 3, digit symbol was a consistent significant predictor of PA across both age groups in waves 2002 and 2011. In 2008, digit symbol was unrelated to PA across both age groups. In wave 2014, digit symbol was significantly related to PA in the older adult (0.08*) sample, but not in the middle-aged sample (0.01). Digit symbol was unrelated to LS and NA in both groups, across all waves, except in 2008. In 2008, digit symbol was a significant predictor of LS in middle-aged adults (0.05*), but not older adults (0.04). Digit symbol was unrelated to NA in the middle-aged sample (0.00), but was significantly negatively related to NA in older adults (–0.04*). These age differences were minimal, and inspection of 95% confidence intervals for the coefficients were overlapping, suggesting that these differences were not significant. Thus, there was no evidence that age moderated the relationship between digit symbol performance and subjective well-being.

Longitudinal data analyses

Cross-lagged panel analyses were conducted to better understand the relationship between digit symbol and PA (which showed the strongest and most consistent relationship to digit symbol). Nine hundred and thirteen participants completed testing at all four waves. Only participants who completed assessment of PA at all four time points were included in the cross-lagged panel analysis ($n = 621$).

Before examining the fit of the different cross-lagged panels described in the Methods section, the invariance of the longitudinal factor loadings from the PA construct were examined. The variances of the PA constructs were set to 1.0. In Model 1, the factor loadings were allowed to vary across the time points. In Model 2, the factor loadings were constrained to be equal across time (for example, the magnitude of loading of parcel 1 onto the PA construct at time 1 was constrained to be equal to the magnitude of the loading of parcel 1 onto the PA construct at times 2,3, and 4). As can be seen in Table 4, the fit of Model 1 was excellent and constraining the factor loadings to be invariant over time did not yield a significantly worse model fit by any of the indicators, including change in X^2 (11.27) by change in df (15; $p = 0.733$). Invariance of the longitudinal factor loadings provide a foundation of conducting the examination of the temporal relationships.

For the cross-lagged panel analyses, age, self-rated health, marital status, and income at baseline were included as covariates that predicted PA and digit symbol at each time point. In addition, loneliness and depression from each wave were entered as covariates and predicted PA and digit symbol associated with each respective wave. Paths that were not significant between the covariates and the outcomes were excluded from the final model. The factor loadings from the PA parcels to the PA construct were constrained to be equal across time. Inspection of Table 4 shows that the four models (M3-M6) fit the data comparably, with almost no differences in fit across the models. This therefore suggests that the autoregressive model is likely the best representation of the data, due to the equivalent fits between the models and the parsimony of the autoregressive model.

Figure 2 depicts the fully cross-lagged model (M6) with standardized coefficients. The cross-lagged coefficients are small and non-significant, indicating that the temporal relationship between digit symbol and positive affect is minimal.

Discussion

The current study provides insight into the relationship between processing speed and subjective well-being. Previous research has shown processing speed to be a particularly robust predictor of well-being (e.g., Enkvist et al., 2013; Wolinsky et al., 2009). Indeed, cross-sectionally across four waves of data in samples of individuals older than 40 years, we found that digit symbol performance was generally a significant predictor of PA, after statistically controlling for the variance accounted for by age, gender, self-rated health, depression, loneliness, marital status, and income. However, digit symbol performance had weaker relationships with LS and NA. The first goal of the current study was to examine whether digit symbol performance predicts different aspects of subjective well-being across

age cross-sectionally; our results show that faster processing speed predicted greater levels of PA. However, these relationships were small in magnitude.

The second goal was to examine whether age moderated the relationship between digit symbol and subjective well-being. After accounting for the variance in subjective well-being that can be explained by health, processing speed, gender, loneliness, depression, marital status, and income, the unique relationships between age and LS and age and NA were significant. Consistent with previous research (e.g., Rossi & Rossi, 1990), age was associated with decreases in levels of NA such that as age increased, ratings of NA decreased. Similar to previous work by Siedlecki et al. (2008, 2012), we found that age was generally associated with increases in ratings of LS. The unique relationship between age and PA was negative in three of the waves. These results are consistent with other findings that support the “paradox of well-being” such that increased age is associated with higher levels of well-being (at least in regards to greater LS and less NA) despite age-associated losses (e.g., Isaacowitz & Smith, 2003; Mroczek & Kolarz, 1998). However, we did not find evidence that age moderated the relationships between processing speed and subjective well-being. Previous work found that fluid ability did not predict life satisfaction in older adults but did so in younger and middle-aged adults (Siedlecki et al., 2008). Our findings, however, suggest that the impact of processing speed on well-being has similar predictive validity for subjective well-being in both middle-aged and older adults. Within the framework of the value-as-a-moderator model (Oishi et al., 1998), this suggests that processing speed may be similarly valued across age.

The third goal of the study was to use cross-lagged panel analysis to examine the longitudinal relationships between processing speed and subjective well-being and assess whether subjective well-being or digit symbol is a stronger temporal predictor of the other. Since only PA demonstrated a consistent and significant relationship with digit symbol cross-sectionally, we focused our examination on the cross-lagged relationship between PA and digit symbol. Our results indicate that the temporal relationship between digit symbol and PA was minimal, and non-significant.

Limitations of the current study include limited generalizability that may be manifested in several ways. First, the sample comprised German adults, of which a majority were White. Second, the sample comprised mainly individuals who reside in the community. Thus, it is unclear whether the current findings would generalize to more diverse samples, including those who reside in institutional settings. Third, our analyses included only individuals who completed the digit symbol task, which may also limit generalizability of the findings (due to response rate bias and panel attrition). An additional limitation of our study was that, while our analyses were in line with previous work (e.g., Gana et al., 2013), our use of cross-lagged panel analyses and cross-sectional latent variable analyses fail to account for potential unobserved heterogeneity. Finally, processing speed was the only measure of cognition obtained.

In conclusion, the results of the current study indicate that in a large community based representative sample of German middle-aged and older adults, there is a weak but consistent relationship between processing speed and positive affect in cross-sectional

samples. Longitudinally, however, the relationship between PA and processing speed is close to zero.

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Ethical Statement

Per Romswinkel et al. (2018), an ethical statement was not necessary for the German Ageing Survey (DEAS) because there was little to no risk to participants, information about the purpose of the study was available to the participants, and the level of examination of the participants did not meet criteria to require an ethical statement. This rationale is supported by the German Research Foundation-guidelines (Deutsche Forschungsgemeinschaft, DFG) available at: http://dfg.de/foerderung/faq/geistes_sozialwissenschaften/ (in German). The DEAS meets the ethical standards delineated in the 1964 Declaration of Helsinki and its amendments. Although there is no ethical statement, consent for participation was requested by a joint written request of the Research Data Centre of the German Centre of Gerontology (DZA) and Infas (Institute of Applied Social Sciences), the institute that conducted field interviewing. Consent was obtained for saving participant addresses for purposes of prospective contact for participation in the longitudinal survey.

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Figure 1.

Conceptual model for the cross-sectional structural equation models.

LS = life satisfaction. PA = positive affect. NA = negative affect. E = error term. For presentation purposes, covariates (age, gender, self-rated health, loneliness, depression, marital status, and income), as well as disturbance terms for the latent variables are not depicted in the model.

Figure 2.

Fully cross-lagged model of positive affect and digit symbol.

PA = Positive Affect. DS = Digit Symbol. D = disturbance. P = positive affect indicator. For presentation purposes, the covariates (age, self-rated health, loneliness, depression, marital status, and income) are not depicted in the model. In addition, one indicator for each latent construct is not depicted, for presentation purposes. * $p < 0.01$

Table 1.

Means and standard deviations of participant characteristics across all waves.

	2002	2008	2011	2014
	<i>N</i> = 3,724	<i>N</i> = 6, 145	<i>N</i> = 4,121	<i>N</i> = 8,174
Digit symbol	40.77 (14.82)	42.69 (14.20)	44.51 (13.99)	44.21 (13.81)
LS	3.81 (0.78)	3.78 (0.74)	3.86 (0.71)	3.81 (0.73)
PA	3.50 (0.78)	3.53 (0.74)	3.54 (0.52)	3.55 (0.52)
NA	2.02 (0.78)	2.02 (0.74)	2.05 (0.52)	2.09 (0.53)
Age	60.47 (11.78)	61.69 (11.74)	64.83 (10.88)	63.75 (11.43)
Gender	51.3% male	49.9% male	49.9% male	50.1% male
Self-rated health	2.47 (0.84)	2.45 (0.85)	2.49 (0.83)	2.50 (0.82)
Loneliness	1.71 (0.78)	1.75 (0.74)	1.75 (0.52)	1.78 (0.54)
Depression	7.20 (6.78)	6.22 (6.74)	6.51 (6.07)	6.78 (6.13)
Income	2265.17 (2083.78)	2604.12 (2083.74)	2830.31 (2291.99)	2945.24 (2083.01)
Marital status	1.27 (0.84)	1.29 (0.45)	1.28 (0.45)	1.31 (0.46)

LS = life satisfaction. PA = positive affect. NA = negative affect.

Table 2.

Correlation matrix for variables in the 2014 wave.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Digit symbol	1									
2. LS	.05 *	1								
3. PA	.18 *	.46 *	1							
4. NA	.01	-.40 *	-.30 *	1						
5. Age	-.47 *	.11 *	-.11 *	-.17 *	1					
6. Gender	.18**	.03 *	.06 *	.14 *	-.08 *	1				
7. Self-rated health	-.22 *	-.33 *	-.33 *	.23 *	.12 *	-.02	1			
8. Loneliness	-.07 *	-.48 *	-.40 *	.42 *	-.05 *	-.08 *	.20 *	1		
9. Depression	-.13 *	-.40 *	-.36 *	.48 *	-.02	.10 *	.48 *	.34 *	1	
10. Marital status	-.07 *	-.19 *	-.06 *	.03 *	.01	.13 *	.05 *	.10 *	.13 *	1
11. Income	.26 *	.21 *	.18 *	-.05 *	-.20 *	-.07 *	-.18 *	-.12 *	-.16 *	-.28 *

LS = life satisfaction. PA = positive affect. NA = negative affect. Valid *N* range from 6,622–8,174*
 $p < .01$

Table 3.

Standardized coefficients predicting subjective well-being components.

	2002			2008			2011			2014		
	Middle	Older	Full	Middle	Older	Full	Middle	Older	Full	Middle	Older	Full
	<i>n</i> = 2,336	<i>n</i> = 1,388	<i>N</i> = 3,724	<i>n</i> = 3,454	<i>n</i> = 2,691	<i>N</i> = 6,145	<i>n</i> = 2,021	<i>n</i> = 2,100	<i>N</i> = 4,121	<i>n</i> = 4,268	<i>n</i> = 3,906	<i>N</i> = 8,174
digit symbol -> LS	0.03	-0.01	0.02	0.05*	0.04	0.05*	0.00	0.06	0.03	0.01	0.02	0.01
digit symbol -> PA	0.09*	0.11*	0.11*	-0.02	0.04	0.01	0.08*	0.13*	0.12*	0.01	0.08*	0.05*
digit symbol -> NA	0.03	0.02	0.03	0.00	-0.04*	-0.01	0.02	-0.06	-0.01	-0.01	-0.03	-0.02
health -> LS	0.19*	0.22*	0.20*	0.04*	0.09	0.06*	0.17*	0.24*	0.20*	0.18*	0.21*	0.19*
health -> PA	-0.16*	-0.16*	-0.16*	-0.10*	-0.14*	-0.12*	-0.11	0.15*	-0.14*	-0.13*	-0.19*	-0.15*
health -> NA	0.05	0.00	0.03	0.05*	0.02	0.02	0.02	0.03	0.03	0.04	0.02	0.02
Sex -> LS	-0.09*	-0.01	-0.06	0.04*	0.03	0.04*	-0.04	-0.04	-0.05*	-0.06*	-0.05*	-0.06*
Sex -> PA	0.00	0.04	0.03	-0.02	-0.02	-0.03	0.03	0.03	0.03	0.04*	0.03	0.04*
Sex -> NA	0.12*	0.08*	-0.03	0.13*	0.08*	0.11*	0.13*	0.10*	0.12*	0.04*	0.14*	0.14*
age -> LS	-0.13*	-0.03	-0.18*	0.07*	0.02	0.07*	-0.06*	-0.04	-0.15*	-0.05*	-0.06*	-0.11*
age -> PA	0.03	-0.02	0.03	-0.06*	-0.10*	-0.15*	0.00	-0.11*	-0.05*	0.01	-0.12*	-0.08*
age -> NA	-0.05	-0.08*	-0.13*	-0.03	-0.08*	-0.08*	-0.07*	-0.13*	-0.13*	-0.09*	-0.07*	-0.14*
loneliness-> LS	0.35*	0.35*	0.35*	0.74*	0.72*	0.73*	0.39*	0.34*	0.37*	0.38*	0.35*	0.37*
loneliness-> PA	-0.35*	-0.29*	-0.33*	-0.66*	-0.62*	-0.63*	-0.35*	-0.27*	-0.31*	-0.33*	-0.32*	-0.32*
loneliness-> NA	0.30*	0.22*	0.27*	0.62*	0.58*	0.60*	0.34*	0.36*	0.35*	0.32*	0.32*	0.32*
CESD-> LS	0.22*	0.28*	0.24*	-0.06*	-0.10*	-0.08*	0.22*	0.22*	0.22*	0.22*	0.21*	0.22*
CESD-> PA	-0.14*	-0.27*	-0.18*	-0.07*	-0.01	-0.05*	-0.25*	-0.21*	-0.23*	-0.26*	-0.15*	-0.21*
CESD-> NA	0.40*	0.41*	0.40*	0.24*	0.20*	0.22*	0.42*	0.33*	0.38*	0.43*	0.36*	0.40*
Marital status-> LS	0.06*	0.03	0.06*	-0.03	-0.04	-0.04	0.11*	0.07*	0.09*	0.15*	0.06*	0.11*
Marital status-> PA	0.04	0.04	0.04	0.10*	0.07*	0.08*	0.04	0.02	0.02	0.03	0.03	0.02
Marital status-> NA	-0.00	-0.05	-0.03	-0.07*	-0.12*	-0.10*	-0.08*	-0.08*	-0.08*	-0.02	-0.09*	-0.05*
Income -> LS	-0.18*	-0.09*	-0.15*	-0.04*	-0.02	-0.03*	-0.14*	-0.10*	-0.12*	-0.13*	-0.12*	-0.13*

	2002			2008			2011			2014		
	Middle	Older	Full	Middle	Older	Full	Middle	Older	Full	Middle	Older	Full
	<i>n</i> = 2,336	<i>n</i> = 1,388	<i>N</i> = 3,724	<i>n</i> = 3,454	<i>n</i> = 2,691	<i>N</i> = 6,145	<i>n</i> = 2,021	<i>n</i> = 2,100	<i>N</i> = 4,121	<i>n</i> = 4,268	<i>n</i> = 3,906	<i>N</i> = 8,174
Income -> PA	0.13 *	0.05	0.10 *	0.04	0.05	0.04 *	0.07 *	0.08 *	0.07 *	0.09 *	0.05 *	0.07 *
Income -> NA	0.09 *	0.07	0.08 *	0.02	0.06 *	0.02	-0.01	-0.00	-0.01	0.02	-0.00	0.01

LS = life satisfaction; PA = positive affect; NA = negative affect

* $p < .01$

Table 4.

Goodness of fit Statistics for the Cross-lagged Panel Analyses.

	χ^2	df	χ^2/df	p	CFI	RMSEA	90% CI of RMSEA
M1: Model with free factor loadings	38.99	20	1.95	0.007	0.996	0.018	0.009, 0.027
M2: Model with invariant longitudinal factor loadings	59.71	35	1.71	0.006	0.995	0.016	0.008, 0.022
M3: Autoregressive	1404.19	526	2.67	<0.001	0.906	0.053	0.049, 0.056
M4: Digit symbol -> PA	1399.88	523	2.68	<0.001	0.907	0.052	0.049, 0.055
M5: PA -> Digit symbol	1402.73	523	2.68	<0.001	0.907	0.052	0.049, 0.055
M6: Fully cross-lagged model	1398.42	520	2.69	<0.001	0.907	0.052	0.049, 0.056

PA = positive affect