Current Psychology (2025) 44:302–318
https://doi.org/10.1007/s12144-024-06956-9

Investigating the bidirectional association between executive functions and well-being in middle-aged and older adults: a cross-lagged modeling approach

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Accepted: 4 November 2024 / Published online: 20 December 2024

Abstract
The direction of the relationship between executive functions (EF) and well-being in terms of healthy aging is poorly understood. Further, notwithstanding theoretical differences regarding the multidimensional nature of well-being, few studies have thoroughly clarified the empirical distinctions between hedonic (i.e., happiness through pleasure and life satisfaction) and eudaimonic (i.e., psychological and social) well-being. Therefore, using a large-scale longitudinal dataset, we investigated the bidirectional associations between EF and three facets of well-being (hedonic well-being, psychological well-being, and social well-being) and whether these relationships differed between middle-aged and older adults. Using autoregressive cross-lagged modeling, we found that the latent variable of EF positively predicted eudaimonic well-being for older adults 9 years later. However, we observed no such relationship for middle-aged adults. Our findings highlight the importance of considering the multifaceted construct of well-being and age-related discontinuity in the associations between EF and well-being.

Keywords Executive functions · Hedonic well-being · Eudaimonic well-being · Psychological well-being · Social well-being · Age-related discontinuity

Introduction

With a rapidly increasing aging population, there is growing research interest in understanding crucial psychological predictors of well-being in mid- and late life. Specifically, in the context of successful aging, executive functions (EF; i.e., a set of higher-order cognitive processes that enable goal-oriented control over one's behaviors, thoughts, and feelings) have received considerable attention as a vital capacity for older adults' well-being (Charles, 2010). For example, better prospective memory, which implicates executive processing, has been shown to facilitate older adults' instrumental activities of daily living, which are essential for maintaining autonomy and, ultimately, well-being in late life (Woods et al., 2015). Further, age-related declines in core cognitive abilities, including EF, memory, processing speed, and reasoning, have been shown to be associated with reductions in functional status, well-being, and poorer quality of life (Boyle et al., 2012).

Despite the empirical importance of EF as a predictor of well-being in middle and old age, previous studies are limited in three respects. First, most are cross-sectional (e.g., Woods et al., 2015) and are thereby unable to delineate the direction of the associations between EF and well-being in mid- and late life. Second, many studies have narrowly conceptualized and operationalized the multidimensional construct of well-being, despite a common theoretical framework of well-being that distinguishes hedonic well-being (HWB; i.e., happiness through pleasure and life satisfaction) from eudaimonic well-being (EWB; i.e., happiness through meaning and purpose). For instance, by using a single composite score, well-being was often treated as a unidimensional construct (e.g., Merten et al., 2022); this

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can hinder more nuanced understanding of the relationships between specific EF abilities and distinct facets of well-being. Third, past studies that relied on single measures of EF have been criticized for the task impurity problem (Miyake et al., 2000), since performance in individual EF tasks implicates both task-specific EF abilities (updating, inhibition, and shifting) and idiosyncratic non-EF abilities, such as color discrimination and reading abilities (Miyake & Friedman, 2012). Therefore, to mitigate measurement errors stemming from non-EF processes, it is critical that we include multiple EF tasks (Snyder et al., 2015) and use a latent variable approach to better capture the intended cognitive abilities (Toh et al., 2020; Zahodne et al., 2014).

In view of these limitations, our goals were threefold. First, using longitudinal cross-lagged modeling analysis, we aimed to shed light on the direction of the relationship between EF and both hedonic and eudaimonic (psychological and social) aspects of well-being. Second, given that previous studies combined a wide range of ages—young, middle-aged, and older adultsand typically assumed similar associations between middle-aged and older adults despite their distinct developmental characteristics (Ihle et al., 2021), we aimed to investigate how the patterns of relationships between EF and facets of well-being would unfold between middle-aged (ages 40 to 64) and older adults (ages 65 and above). And third, using a rigorous latent variable approach, we aimed to tackle the task-impurity problem inherent in studies of EF.

Hedonic and eudaimonic approaches to well-being

Hedonic well-being (HWB) is defined as the degree to which positive affect outweighs negative affect (i.e., affective well-being) as well as life satisfaction and fulfillment (i.e., cognitive well-being) in various life domains such as health, job, and relationships (Diener et al., 2018). However, well-being encompasses more than HWB, since it includes positive functioning, the pursuit of worthwhile goals, and meaningful activities. Eudaimonic well-being (EWB), which comprises psychological well-being and social well-being, equates happiness with human potential that may lead to positive personal functioning (Petrillo et al., 2018). Specifically, psychological well-being reflects the extent to which individuals are functioning well in their personal life (Ryff & Keyes, 1995). This construct is represented by six dimensions of psychological functioning: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance. Social well-being, on the other hand, pertains to the degree to which individuals are thriving in their interactions and connections within a broader societal context (Keyes, 2007). Social well-being consists of five aspects: social integration, social contribution, social coherence, social actualization, and social acceptance. Accordingly, the functional well-being approach (Vittersø, 2013) posits that HWB and EWB contribute differently to the dynamics of a good life.

Despite the fact that HWB and EWB are highly correlated with each other, accumulating evidence lends support to their distinctions. For instance, factor analytic studies have supported a three-dimensional structure of well-being that includes hedonic, psychological, and social well-being (e.g., Petrillo et al., 2015). However, scant research has simultaneously examined the unique relations of both HWB and EWB to executive functioning within the same statistical model. Therefore, to more precisely estimate the association between EF and “a good life” in middle and old age, it is critical that we consider the multifaceted aspects of well-being and establish each facet’s unique association with EF above and beyond the other facets of well-being.

Executive functions and well-being

Broadly, comprehensive models of EF suggest that higher-order complex skills, such as reasoning, problem solving, and planning, are rooted in EF (core cognitive control) abilities (Miyake et al., 2000). Although many cognitive processes have been ascribed to EF, three primary functions emerged as core components to the construct: (a) updating, as the ability to mentally manage goal-relevant information; (b) inhibition, as the ability to suppress inappropriate prepotent actions; and (c) task switching (or shifting), as the capacity to shift attention between multiple cognitive operations.

EF as a predictor of well-being Despite growing interest in studying the relationship between EF and (hedonic and/or eudaimonic) well-being, the literature offers only limited understanding due to mixed results; the direction of their relationships, especially in middle-aged and older adults, is also unclear (Ihle et al., 2021). Several theoretical accounts postulate the predictive role of EF in HWB and EWB in middle and late adulthood. According to the model of successful aging, promoting cognitive abilities is advantageous for aging (Rowe & Kahn, 1997). Indeed, Krueger et al. (2009) maintain that individuals with better cognition are more likely to be active and engaged with life as they age, which in turn facilitates well-being in terms of happiness. Likewise, older adults’ limited engagement in activities can reduce their EWB due to less frequent experiences of feelings of purposefulness. Relatedly, the activity restriction model of depressed affect suggests that reduced cognitive functioning in old age hampers one’s performance in personal and social activities, which in turn results in higher depressed mood (Williamson et al., 1998). The strength and vulnerabilities integration model (Charles, 2010) also posits that aging-related vulnerabilities, such as a decline in cognitive abilities, reduce the capacity to employ effective emotion regulation strategies and draw on experiences and skills to continue living an engaged life, which contributes to EWB.

In favor of these theoretical models, several longitudinal studies have reported that older adults' better cognitive performance in terms of spatial abilities and processing speed—which are critical aspects of EF in older adults—predicted higher subsequent life satisfaction 3 years later (e.g., Enkvist et al., 2013). A recent large-scale cross-sectional study also found that middle-aged and older adults' executive processing predicts life satisfaction via improved sense of control (Toh et al., 2020). These findings corroborate experimental studies that demonstrate the beneficial effects of cognitive interventions on subsequent subjective well-being in terms of affective well-being and life satisfaction (e.g., Chan et al., 2018).

In a similar vein, studies also suggest a positive association between executive functioning and EWB. It is thought that one's ability to self-reflect, integrate life experiences into a cohesive narrative, regulate one's emotions, and understand one's significance within the broader context are essential for developing and maintaining purpose in life, which is a core aspect of EWB (Toh & Yang, 2024). Given that cognitive control processes are essential to maintain one's capacity to engage in such cognitive, motivational, and emotional goals (Kryla-Lighthall & Mather, 2009), it is plausible that executive functioning positively predicts EWB.

Well-being as a predictor of EF Another stream of studies suggests that well-being, or the absence thereof, may be one of the forces that lead to adverse cognitive changes. Several cross-sectional studies suggest that specific facets of well-being predict cognitive and executive functioning in old age (e.g., Gale et al., 2012). For instance, life satisfaction in middle and late adulthood has been shown to be important for overall cognitive functioning, as measured by the Mini-Mental State Examination (MMSE; Rowe & Cosco, 2016). Patients diagnosed with depressive disorders (an indicator of low HWB) are also found to have poor performance on cognitive tasks (Bäckman et al., 1996). Small to moderate positive correlations between aggregated HWB and cognitive functioning were also found in older adults (Gale et al., 2012). Although cognitive functioning was assessed by various measures of reasoning, memory, perceptual speed, knowledge, fluency, and Raven's Standard Progressive Matrices (Gale et al., 2012), performance on these tests has been suggested to depend on EF processes.

Similarly, EWB has been shown to serve as a protective buffer against cognitive decline via better health behaviors and more stimulating cognitive exercise and activities. For instance, empirical evidence suggests that higher levels of purpose in life are related to slower cognitive decline in older adults (e.g., Kim et al., 2019) as well as reduced risk of developing mild cognitive impairment (Boyle et al., 2012). Moreover, purpose in life is positively associated with cognitive functioning (i.e., EF) after adjusting for covariates (Lewis et al., 2017), and the pursuit of meaningful goals is thought to reduce the risk of cognitive decline (Whatley et al., 2022). EWB may also indirectly influence cognitive functioning via processes related to self-evaluation and self-regulation. For example, individuals who are more engaged with life are more likely to set and persist in pursuing cognitively demanding goals, which provide more opportunities for cognitive engagement (e.g., Krueger et al., 2009).

Mixed findings Some mixed findings have been reported, which implies either a bidirectional relationship between cognitive abilities (i.e., EF) and well-being or little or no relationship. Specifically, Wilson et al. (2013) found that better global cognition, as indexed by a composite score based on multiple tasks that assess perceptual speed and memory annually over an average of 5 to 6 years, predicted higher purpose in life (i.e., EWB) at a later time; higher purpose in life also predicted better subsequent cognitive functioning.

On the other hand, Comijs et al. (2005) found, in a longitudinal study consisting of three waves over a period of 6 years, that a steeper decline in cognitive performance—as indexed by changes in MMSE scores over two subsequent 3-year periods—was associated with lower levels of HWB in terms of feelings of loneliness, but this longitudinal association was not found for life satisfaction. However, Braun et al. (2017) reported that cognitive functioning, as assessed by standard psychometric tests of fluid cognitive abilities, was not related to longitudinal change in HWB in terms of life satisfaction across two waves over a period of 12 years.

The moderating role of age

A possible explanation for the mixed findings regarding the relationship between EF and well-being is the limited consideration of discontinuous aging processes across the lifespan. Empirical evidence highlights several behavioral and cognitive differences between middle-aged and older adults. For example, physical activity has been found to provide a sense of purpose and continued engagement for older adults, but does not have the same significance for middle-aged adults (Belon et al., 2016). Also, middle-aged individuals often shoulder responsibilities such as financial obligations, work-related demands, and caregiving duties, since they are typically at the peak of their productivity (Lachman et al., 1994). In contrast, older adults face distinct developmental challenges, including adjustment to retirement, managing health declines and cognitive changes, and coping with the loss of a spouse, social isolation, and loneliness (Schaie & Willis, 2010). Despite these distinctions, much of the literature has largely assumed similar associations between EF and well-being for middle-aged and older adults (Ihle et al., 2021); few studies have examined age-related changes in the association between EF and well-being. However, theoretical models of discontinuous aging suggest qualitatively distinct, rather than gradual, changes throughout the lifespan (e.g., Baltes & Smith, 2003), which likely contribute to differences in the relationships between EF and well-being when comparing middle-aged and older adults. Consequently, it is unclear whether the relationships between EF and hedonic well-being, psychological well-being, and social well-being vary qualitatively across different age groups. This uncertainty underscores a research gap the present study aimed to address.

The Present Study

Our primary research goas are to (a) examine the longitudinal bidirectional relationship between EF and multidimensional facets of well-being, including HWB, psychological, and social well-being; (b) investigate age-related qualitative differences in the patterns of relationships between EF and facets of well-being between midlife (ages 40 to 64) and late life (ages 65 and above) samples; and (c) employ a latent variable approach to address the task-impurity problem inherent in studies on the association between EF and well-being.

To this end, we analyzed data from the Midlife in the United States (MIDUS 2 and 3) studies and the accompanying Cognitive Project in both MIDUS 2 and 3. This large-scale longitudinal dataset provides extensive data on a population-based cohort ranging from their 40s to their 80s over a 9-year period. These rich, heterogeneous, and nationally representative data allowed us to examine in greater depth the potential bidirectional relationships between EF and multidimensional aspects of well-being over an extended timeframe and capture changes as participants transitioned from middle age to old age and from old age to very old age.

Method

Participants

Participants who completed the second and third waves of the MIDUS national longitudinal study (i.e., MIDUS 2 and 3) were included in our analyses. The first wave of the MIDUS study was excluded from the analysis because the cognitive measure of the Brief Test of Adult Cognition (BTACT; Lachman et al., 2014) was not administered during this phase. MIDUS 1 generated a probability sample ($N = 7{,}100$) in 1995–1996 through random-digit dialing of U.S. households across 48 states with an oversample of those between 40 and 60 years of age (age range = 24–75; $M_{age} = 46.40$, $SD_{age} = 13.00$; see Brim et al., 2004). MIDUS 2 was conducted with 75% of the original sample after 9 years ($N = 4{,}955$), and MIDUS 3 was conducted with 76.9% of the eligible sample from the MIDUS 2 ($N = 3{,}294$) 9.12 years later. For the purposes of our study, we only considered participants who were aged 40 or above in wave 2 ($N = 2{,}992$; age range = 40–84; $M_{\mathrm{age}} = 56.3$, $SD_{\mathrm{age}} = 10.3$) and wave 3 (age range = 48–93; $M_{\mathrm{age}} = 65.4$, $SD_{\mathrm{age}} = 10.3$; see Table 1 for descriptive statistics).

Measures

Life satisfaction Life satisfaction was assessed using the 6-item life satisfaction scale (Prenda & Lachman, 2001). Participants were asked to rate how satisfied they were across multiple life domains: work, financial situation, health, relationship with partner (if applicable), relationship with children (if applicable), and overall life (0 = *the worst possible*, 10 = *the best possible*). Higher mean scores reflect higher levels of life satisfaction across these domains ($\alpha_{\mathrm{MIDUS\ 2}} = 0.70$; $\alpha_{\mathrm{MIDUS\ 3}} = 0.70$).

Positive and negative affect Affective well-being was assessed using the 9-item Positive and Negative Affect Schedule (PNAS; Mroczek & Kolarz, 1998). Participants rated the extent to which they had experienced positive ($\alpha_{\mathrm{MIDUS\ 2}} = 0.85$, $\alpha_{\mathrm{MIDUS\ 3}} = 0.86$) and negative emotions ($\alpha_{\mathrm{MIDUS\ 2}} = 0.79$, $\alpha_{\mathrm{MIDUS\ 3}} = 0.80$) on a 5-point scale (1 = *all of the time*, 5 = *none of the time*) during the past 30 days. Responses were reverse-coded, with higher scores denoting higher positive and negative affectivity, respectively.

Psychological well-being Psychological well-being was assessed using the 42-item Psychological Well-Being Scale (Ryff & Keyes, 1995). Participants reported their agreement with each statement using a 7-point scale (1 = *strongly agree*, 7 = *strongly disagree*). The scale contains six subscales: (a) autonomy ($\alpha_{\mathrm{MIDUS\ 2}} = 0.71$, $\alpha_{\mathrm{MIDUS\ 3}} = 0.69$); (b)

Table 1 Descriptive statistics of MIDUS 2 and MIDUS 3

	MIDUS 2 (2004–2006)					MIDUS 3 (2013–2014)				
	Mean (SD)	Range	N	Kurtosis	Skewness	Mean (SD)	Range	N	Kurtosis	Skewness
Demographics										
Age (years)	56.34 (10.29)	40–84	2992	-0.686	0.372	65.43 (10.3)	48–93	2992	-0.685	0.368
Sex (% of male)	45%		2992	-1.963	0.195	45%		2992	-1.963	-0.195
Education	7.43 (2.5)	1–12	2989	-0.976	0.132	7.43 (2.5)	1–12	2989	-0.976	0.132
Health	2.34 (0.95)	1–5	2991	-0.084	0.472	2.59 (1.05)	1–5	2991	-0.37	0.361
Income	75.17 (61.2)	0-300	2554	2.842	1.539	85.13 (72.69)	0-300	2480	1.293	1.294
Cognitive well-being										
Life satisfaction	7.83 (1.08)	2.5–10	1779	1.582	-0.938	7.94 (1.11)	2.5–10	1490	1.711	-1.056
Affective well-being										
Positive affect	3.62 (0.74)	1–5	2615	0.4	-0.523	3.57 (0.77)	1–5	2606	0.496	-0.587
Negative affect	1.51 (0.5)	1–5	2595	4.793	1.743	1.46 (0.51)	1–5	2558	5.216	1.846
Psychological well-being										
Autonomy	37.29 (7.01)	10–49	2620	-0.226	-0.378	37.49 (6.67)	10–49	2640	-0.204	-0.363
Environmental mastery	38.72 (7.34)	11–49	2622	-0.081	-0.624	38.72 (7.4)	10–49	2644	0.04	-0.67
Personal growth	38.96 (6.74)	14–49	2614	-0.001	-0.641	38.34 (6.85)	14–49	2643	-0.389	-0.477
Positive relations	41.06 (6.81)	14–49	2621	0.133	-0.857	40.78 (6.71)	14–49	2625	0.018	-0.782
Purpose in life	39.15 (6.76)	10–49	2622	-0.112	-0.649	38.22 (6.96)	8–49	2620	-0.175	-0.542
Self-acceptance	38.54 (8.24)	9–49	2626	0.347	-0.882	38.27 (8.02)	7–49	2606	0.204	-0.777
Social well-being										
Social coherence	4.69 (1.52)	1–7	2625	-0.863	-0.128	4.54 (1.56)	1–7	2608	-0.876	-0.034
Social integration	4.99 (1.33)	1–7	2619	-0.234	-0.551	4.93 (1.35)	1–7	2593	-0.267	-0.498
Social acceptance	4.75 (1.09)	1–7	2617	0.136	-0.315	4.69 (1.06)	1–7	2579	-0.104	-0.164
Social contribution	5.34 (1.18)	1–7	2618	-0.143	-0.537	5.15 (1.24)	1–7	2581	-0.349	-0.393
Social actualization	4.3 (1.33)	1–7	2617	-0.501	-0.144	3.9 (1.35)	1–7	2573	-0.427	0.039
Executive functions										
Executive functions (zscores)	0.18 (0.96)	-4.64-8	2728	7.424	0.863	-0.19 (0.74)	-5.63-1.98	2466	1.532	-0.45
Backward digit span	5.06 (1.47)	0–8	2722	-0.263	0.213	4.94 (1.49)	0–8	2464	0.003	0.182
Categorical fluency	19.35 (5.91)	1–42	2722	0.143	0.325	18.47 (5.94)	0–40	2461	0.098	0.238
Number series	2.42 (1.51)	0–5	2718	-1.053	0.087	2.27 (1.55)	0–5	2392	-1.099	0.218
Backward counting task	37.94 (10.86)	-2-88	2720	0.544	0.38	35.59 (11.17)	-10-83	2435	0.621	0.225
Stop and Go Switch Task	1.07 (0.24)	0.22–3.77	2635	11.833	2.183	1.28 (0.39)	0.42–7.67	2355	36.32	3.1

Note. Sex (1 = Female, 2 = Male). Education was measured from 1 (No school) to 12 (Doctoral or other professional degree)

Income included wages, salaries, and stipends from all jobs; measurement unit = $1,000,000

environmental mastery ($\alpha_{MIDUS\ 2} = 0.78$, $\alpha_{MIDUS\ 3} = 0.79$); (c) personal growth ($\alpha_{MIDUS\ 2} = 0.74$, $\alpha_{MIDUS\ 3} = 0.75$); (d) positive relations with others ($\alpha_{MIDUS\ 2} = 0.78$, $\alpha_{MIDUS\ 3} = 0.78$); (e) purpose in life ($\alpha_{MIDUS\ 2} = 0.70$, $\alpha_{MIDUS\ 3} = 0.72$); and (f) self-acceptance ($\alpha_{MIDUS\ 2} = 0.84$, $\alpha_{MIDUS\ 3} = 0.84$). Responses were reverse-coded for corresponding subscales, with higher scores denoting higher domain-specific psychological well-being.

Social well-being Social well-being was measured using short forms of the Social Well-Being Scale (Keyes, 2007), with each scale consisting of two to three items: (a) the social coherence scale (i.e., meaningfulness of society) assesses one's capacity to understand the quality of the social world ($\alpha_{MIDUS\ 2} = 0.64$, $\alpha_{MIDUS\ 3} = 0.66$); (b) the social integration scale measures one's degree of involvement with and support of their community ($\alpha_{MIDUS\ 2} = 0.76$, $\alpha_{MIDUS\ 3} = 0.79$); (c) the social acceptance scale (i.e., acceptance of others) measures one's perception of others as compassionate and altruistic ($\alpha_{MIDUS\ 2} = 0.41$, $\alpha_{MIDUS\ 3} = 0.41$); (d) the social contribution scale assesses one's degree of importance to the society ($\alpha_{MIDUS\ 2} = 0.70$, $\alpha_{MIDUS\ 3} = 0.72$); and (e) the social actualization scale measures the degree of one's potential to achieve societal goals ($\alpha_{MIDUS\ 2} = 0.67$, $\alpha_{MIDUS\ 3} = 0.70$). All items were rated on a 7-point scale (1 = *strongly agree*; 7 = *strongly disagree*). If necessary, items were reverse-coded to ensure that higher scores indicate higher levels of their respective constructs.

Executive functions EF was assessed using the Brief Test of Adult Cognition by Telephone (BTACT; Lachman & Tun, 2008), which consists of a battery of five EF tests. Working memory (i.e., updating) was indexed by the highest span of digits participants reproduced in reverse order in the backward digit span task. Verbal fluency was indexed by the number of unique and correct words generated based on a category of animals in 60 s. Inductive reasoning was indexed by the number of accurate responses to a pattern in a series of five numbers in the number series task. Processing speed was indexed by the number of digits correctly produced when tasked to count backward from 100 in 30 s.

Attention switching and inhibitory control was assessed by the Stop and Go Switch Task (SGST; Lachman & Tun, 2008). The task consisted of two single-task blocks (i.e., normal and reverse blocks) to establish baselines and a mixed-task block that required participants to alternate between the two response modes. In the normal block (i.e., congruent trials), participants responded to the stimulus (cue) word "RED" or "GREEN" with "STOP" or "GO," respectively. In the reverse block (i.e., incongruent trials), participants were required to inhibit their typical response (as in the normal block) and give the opposite response—i.e., "RED" to "GO," and "GREEN" to "STOP." The mixed-task block consists of switching between congruent and incongruent trials presented at random intervals. Attention switching ability was indexed by the average difference in reaction times between switch trials in the mixed block, which required participants to switch from one condition to another (e.g., congruent to incongruent trials) and non-switch trials that did not involve a change. Inhibitory control was indexed by the average difference in reaction time between the incongruent and congruent trials in single-task blocks.

Covariates All analyses controlled for covariates (i.e., age, sex, education, household income, subjective health, and personality traits) that have been shown to affect EF and various facets of well-being (e.g., Diener et al., 2018; Kaplan et al., 2018). Education was reported on a 12-point scale (1 = *no school*, 12 = *doctoral or other professional degree*). Subjective health was assessed by asking participants to rate their overall physical health (1 = *excellent*, 5 = *poor*). Household income was assessed based on total income from wages, pensions, social security, and other financial sources. Personality traits were assessed by 31 personality-related adjectives, for each of which participants rated themselves using a 4-point scale (1 = *a lot*, 4 = *not at all*).

Analytical strategy

To study the longitudinal relation between EF and the multidimensional aspects of well-being across two assessment waves, autoregressive cross-lagged modeling (ACLM)—a structural equation modeling for longitudinal data—was employed. ACLM allowed us to control for the levels of each construct assessed at a given time ($\underline{t}$) and estimate the crossed-lagged relationships in the subsequent time ($t+1$; Hamaker et al., 2015). By estimating autoregressive effects (i.e., relationships within the same variables but measured at different times) and cross-lagged effects (i.e., bidirectional relationships between different variables measured on different occasions), ACLM is regarded as an effective method for examining the structural relationships among constructs that are repeatedly measured and estimating their directional influences over time (Hamaker et al., 2015).

To examine whether EF uniquely predicts each aspect of multidimensional well-being and vice versa within the same statistical model, the four main variables (HWB, psychological well-being, social well-being, and EF) across two waves were operationalized as latent variables using confirmatory factor analyses (CFA). The latent variable of HWB was indicated by four parcels based on the nine-item PNAS for affective well-being and six-item life satisfaction scale for cognitive well-being. The four parcels were formed using the item-to-construct balance algorithm (Little et al., 2002) based on loading scores generated by initial CFAs (see Figure 4; Little et al., 2002). Compared with a latent construct based on scale scores, parcelling was shown to enhance power and reduce measurement error (Tomarken & Waller, 2005).

The latent variable of psychological well-being was indicated by six subscale scores: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance. Similarly, the latent variable of social well-being was indicated by five subscale scores for social acceptance, social actualization, social coherence, social contribution, and social integration.

Lastly, in line with the dedifferentiation hypothesis, which posits that the distinction among EF facets diminishes with age, and consistent with previous findings (e.g., de Frias et al., 2009), the latent variable for EF was modeled as a unidimensional one-factor construct based on five indicators: performance on the backward digit span, categorical fluency, number series, backward counting, and SGST. However, given previous studies that have suggested a two-factor structure of EF in older adults (e.g., Adrover-Roig et al., 2012; Hull et al., 2008) and considering the possibility that different facets of EF may show varying associations with different aspects of well-being over time, we also modeled EF as a two-factor construct, which consists of (a) a processing speed factor, indicated by categorical fluency and backward counting tasks and (b) an updating factor, indicated by the number series, backward digit span, and SGST (Khoo & Yang, 2020; Oh & Yang, 2022).

Model fit was assessed by chi-square statistics, the comparative fit index (CFI), the Tucker–Lewis index (TLI), the root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). Acceptable fit was defined as χ^2/df < 2.00, CFI and TLI > 0.90 and 0.95, and RMSEA and SRMR < 0.08 and 0.06 for acceptable and excellent fit, respectively (Marsh et al., 2004).

We examined whether the constructs being measured have invariant measurement properties across both occasions (e.g., Grimm & Ram, 2018). For each of the four variables (EF, hedonic, social, and psychological well-being), three models of measurement invariance were tested: (a) a configural invariance model (i.e., whether the overall factor structure fits well across both timepoints); (b) a metric invariance model (whether factor loadings are equivalent across both timepoints); and (c) a scalar invariance model (whether item intercepts are equivalent across both timepoints). Two criteria were used as evidence of invariance. First, the model should show adequate fit indexes for CFI, TLI, RMSEA and SRMR. Second, changes in the CFI values of the models for the same construct should be less than 0.01 (ΔCFI < 0.01; Cheung & Rensvold, 2002). Observed changes across the time points may be attributed to changes in construct (i.e., alpha change) only when three levels of measurement invariance—configural, metric, and scalar invariance—are achieved.

Results

Measurement models

Adequate model fit was found for the three measurement models for hedonic, psychological, and social well-being (RMSEAs < 0.08, CFIs > 0.90, TLIs > 0.90, and SRMRs < 0.08; for detailed measurement models, see Figures 2, 3, 4, and 5 in the Appendix). As for the measurement model of EF, both the one-factor and two-factor structure of EF, based on the five indicators, provided great fit to the data. In comparing the two models of EF, the one-factor model had smaller AIC and BIC values, which indicates a better fit and more parsimonious model of EF for middle-aged and older adults; a χ^2 difference test could not be used here, because the models were not nested. Nevertheless, we retained the two-factor model of EF to test the relationships between specific aspects of EF (i.e., processing speed and updating) and the multidimensional aspects of well-being.

Measurement invariance

The two assumptions of measurement invariance were examined. Global fit indexes for the three levels of measurement invariance for each latent variable are shown in Table 2. Comparison of models of the same construct demonstrated scalar invariance for HWB, psychological well-being, and social well-being (ΔCFIs < 0.01). However, scalar invariance was not achieved for both the one-factor and two-factor models of EF (ΔCFI = 0.089). Hence, we tested partial scalar invariance on the basis of metric invariance by relaxing the intercept of one indicator at a time. The modified model, in which the intercepts of SGST were relaxed, fit the data well, which indicates partial scalar invariance for the one-factor EF (ΔCFI = 0.001). We also tested measurement invariance for the two-factor model of EF. Similar to the one-factor model, the modified two-factor

Table 2 Measurement invariance for key variables

	Model	χ2	df	RMSEA	CFI	TLI	SRMR	ΔCFI
Executive functions								
One-factor model	Configural	153.485	10	0.076	0.966	0.932	0.027	-
	Metric	164.866	14	0.066	0.964	0.949	0.030	0.002
	Scalar	565.282	18	0.111	0.871	0.856	0.067	0.093
	Partial Scalar	172.227	17	0.061	0.963	0.957	0.031	0.001
Two-factor model	Configural	145.538	8	0.083	0.968	0.920	0.026	-
	Metric	141.267	11	0.070	0.968	0.943	0.027	0.001
	Scalar	541.087	13	0.122	0.879	0.827	0.066	0.089
	Partial Scalar	167.287	14	0.070	0.963	0.943	0.030	0.005
Psychological well-being	Configural	142.393	10	0.071	0.993	0.978	0.016	-
	Metric	156.864	15	0.06	0.992	0.984	0.021	0.001
	Scalar	204.4	20	0.059	0.99	0.985	0.024	0.002
Social well-being	Configural	3.65	2	0.018	1	0.999	0.001	-
	Metric	11.021	5	0.022	0.999	0.998	0.017	0.001
	Scalar	54.5	8	0.048	0.995	0.992	0.031	0.004
Hedonic well-being	Configural	485.262	50	0.074	0.958	0.925	0.051	-
	Metric	498.364	58	0.069	0.958	0.935	0.053	0.000
	Scalar	576.034	66	0.070	0.951	0.933	0.056	0.007

Note. *CFI* comparative fit index, *RMSEA* root mean square error of approximation, *SRMR* standardized root mean square residual, *ΔCFI* change in CFI

Table 3 Latent factor correlations with results for MIDUS 2 in the bottom diagonal and MIDUS 3 in the top diagonal

	Executive functions	Hedonic well-being	Psychological well-being	Social well-being
Executive functions	-	0.164**	0.123*	0.226**
Hedonic well-being	-0.017	-	0.72**	0.454**
Psychological well-being	0.066**	0.822**	-	0.55**
Social well-being	0.204**	0.605**	0.755**	-

model, in which the intercepts of SGST were relaxed, fit the data well, which indicates partial scalar invariance for the two-factor EF (ΔCFI = 0.005).

Main analyses

Given that all measurement models showed acceptable to good fit and moderate to strong factor loadings that were at least scalar (or partially scalar) invariant over time, we used these measurement models to fit the multivariate autoregressive and cross-lagged panel models. Covariates—age, sex, education, household income, overall health, and personality traits—were included as manifest variables in the analyses. Correlations between EF and various facets of well-being at time points 1 and 2 are shown in Table 3 (for correlations between all variables, see Table 7 in the Appendix).

Goodness of fit of the proposed autoregressive cross-lagged path model was acceptable for both middle-aged—χ^2 (1,697) = 10120.097, $p < .01$, RMSEA = 0.050, CFI = 0.962, TLI = 0.948, SRMR = 0.072—and older adults, χ^2 (238) = 4037.546, $p < .01$, RMSEA = 0.051, CFI = 0.928, TLI = 0.910, SRMR = 0.076. Across both the one-factor and two-factor models of EF, we found significant autoregressive paths, which suggest moderate to high temporal stability in EF, psychological well-being, HWB, and social well-being (see Table 4 for autoregressive and cross-lagged paths coefficients).

Crucially, we found age-related differences in the relationships of interest: EF at T1 positively predicted psychological well-being ($B = 0.10$, $p = .049$) and social well-being ($B = 0.12$, $p = .038$) at T2 (9 years later), above and beyond hedonic well-being and covariates for older adults (aged 65 to 84), but not for middle-aged adults (aged 40 to 64). None of the facets of well-being predicted EF in both age groups (Refer to Tables 4, 5 and 6). Consistent with the dedifferentiation hypothesis, we found that results using the two-factor model were similar to those from the one-factor model (refer to Tables 5 and 6). The structural model tested in this study is illustrated in Fig. 1.

Discussion

We examined bidirectional longitudinal relationships between EF and hedonic, psychological, and social facets of well-being in middle and late adulthood. Using ACLM, we found that older, but not middle-aged, adults' EF at T1 positively predicted psychological and social well-being

Table 4 Parameter estimates of the cross-lagged path model for the one-factor model of executive function

	Middle-aged (40–64)				Older Adults (65–84)			
Focal predictors	Executive functions 3	Hedonic well-being 3	Psychological well-being 3	Social well-being 3	Executive functions 3	Hedonic well-being 3	Psychological well-being 3	Social well-being 3
Executive functions 2	0.92**	-0.02	0.03	0.00	0.82**	0.02	0.10*	0.12*
Hedonic well-being 2	0.00	0.64**	0.04	-0.02	-0.02	0.55**	-0.03	-0.21*
Psychological well-being 2	0.00	-0.03	0.46**	0.10	0.04	0.19	0.5**	0.16
Social well-being 2	0.01	0.11*	0.23**	0.65**	0.03	-0.07	0.2**	0.64**
Covariates								
Age 2	-0.16**	0.04	0.00	-0.05*	-0.07	-0.05	-0.05	-0.02
Sex	0.01	-0.02	-0.03	-0.05*	-0.04	-0.02	-0.02	-0.13**
Education 2[1]	0.05*	0.01	0.01	0.13**	-0.06	-0.02	0.00	0.13*
Household income 2	0.05**	0.09**	0.08**	0.05*	0.04	0.1*	0.13**	0.07
Subjective health 2	0.02	0.06	0.03	0.05	0.10	0.13*	0.01	0.10
Extraversion 2	-0.01	-0.03	0.04	0.03	-0.05	-0.05	0.06	0.09
Neuroticism 2	-0.02	-0.04	-0.07**	-0.01	-0.04	-0.04	-0.09	-0.11*
Openness to experience 2	0.02	-0.02	-0.02	0.00	0.03	-0.03	0.06	-0.01
Conscientiousness 2	0.04	0.05*	0.07**	-0.05*	-0.11**	0.03	0.04	-0.09
Agreeableness 2	-0.05**	0.00	0.00	0.00	-0.04	0.10	-0.06	-0.06

Note. Sex (1 = Female, 2 = Male). Executive Function 2 = Executive Function at MIDUS 2; Executive Function 3 = Executive Function at MIDUS 3

[1]Education was measured from 1 (No school) to 12 (PhD, EDD, MD, DDS, LLB, LLD, JD or other professional doctorate)

Table 5 Parameter estimates of the cross-lagged path model for the two-factor model of executive function (processing speed)

	Middle-aged (40–64)				Older adults (65–84)			
Focal predictors	Executive function 3 A	Hedonic well-being 3	Psycho-logical well-being 3	Social well-being 3	Executive function 3 A	Hedonic well-being 3	Psycho-logical well-being 3	Social well-being 3
Executive Function 2 A[1]	0.87**	-0.01	0.03	0.04	0.77**	0.05	0.12*	0.15*
Hedonic Well-being 2	-0.03	0.65**	0.04	-0.01	-0.07	0.53**	-0.04	-0.22*
Psychological Well-being 2	0.02	-0.03	0.46**	0.09	0.08	0.19	0.52**	0.19
Social Well-being 2	0.01	0.11*	0.23**	0.65**	0.00	-0.07	0.19*	0.62**
Covariates								
Age 2	-0.18**	0.04	0.00	-0.04	-0.06	-0.06	-0.06	-0.02
Sex	0.00	-0.02	-0.03	-0.05*	-0.07	-0.02	-0.01	-0.12*
Education 2[2]	0.05	0.00	0.01	0.13**	-0.05	-0.02	0.01	0.13*
Household Income 2	0.08**	0.09**	0.08**	0.05*	0.01	0.1**	0.13**	0.07
Subjective Health 2	-0.03	-0.06	-0.03	-0.05	-0.15*	-0.14*	-0.01	-0.11
Extraversion 2	0.00	-0.03	0.04	0.03	-0.05	-0.03	0.06	0.09
Neuroticism 2	-0.04	-0.04	-0.07**	-0.01	0.00	-0.06	-0.09*	-0.11*
Openness to Experience 2	0.02	-0.02	-0.02	0.00	0.08	-0.05	0.05	-0.02
Conscientiousness 2	0.03	0.05*	0.07**	-0.05*	-0.11*	0.03	0.04	-0.09
Agreeableness 2	-0.05	0.00	0.00	0.00	-0.02	0.1*	-0.05	-0.06

Note. Sex (1 = Female, 2 = Male). Executive Function 2 = Executive Function at MIDUS 2; Executive Function 3 = Executive Function at MIDUS 3

Executive Function A is characterized by a processing speed construct, indexed by categorical fluency and backward counting tasks

[2]Education was reported on a scale of 1 (no school) to 12 (PhD, EDD, MD, DDS, LLB, LLD, JD or other professional doctorate)

Table 6 Parameter estimates of the cross-lagged path model for the two-factor model of executive function (updating)

	Middle-aged (40–64)				Older adults (65–84)			
Focal predictors	Executive function 3 B	Hedonic well-being 3	Psycho-logical well-being 3	Social well-being 3	Executive function 3 B	Hedonic well-being 3	Psycho-logical well-being 3	Social well-being 3
Executive Function 2 B[1]	0.89**	-0.03	0.00	-0.01	0.93**	-0.01	0.12*	0.15*
Hedonic Well-being 2	-0.03	0.65**	0.04	-0.02	0.00	0.54**	-0.03	-0.22*
Psychological Well-being 2	-0.07	-0.03	0.46**	0.10	-0.02	0.19	0.5**	0.16
Social Well-being 2	0.04	0.11*	0.23**	0.65**	0.13	-0.06	0.21**	0.64**
Covariates								
Age 2	-0.2**	0.04	0.00	-0.05*	-0.17**	-0.06	-0.05	-0.02
Sex	0.03	-0.02	-0.03	-0.05*	0.03	-0.02	-0.02	-0.12**
Education 2[2]	0.17**	0.01	0.01	0.14**	-0.03	0.00	0.00	0.12*
Household Income 2	0.03	0.09**	0.08**	0.05*	0.09	0.1**	0.13**	0.07
Subjective Health 2	-0.04	-0.06	-0.03	-0.05	-0.07	-0.14*	0.00	-0.10
Extraversion 2	-0.03	-0.03	0.04	0.03	-0.11	-0.03	0.06	0.09
Neuroticism 2	-0.03	-0.04	-0.07**	-0.01	-0.09	-0.05	-0.08	-0.11*
Openness to Experience 2	0.04	-0.02	-0.02	0.00	0.07	-0.04	0.06	-0.01
Conscientiousness 2	0.06*	0.05*	0.07**	-0.05*	-0.13*	0.04	0.04	-0.09
Agreeableness 2	-0.07*	0.00	0.00	0.00	-0.14*	0.11*	-0.05	-0.06

Note. Sex (1 = Female, 2 = Male). Executive Function 2 = Executive Function at MIDUS 2; Executive Function 3 = Executive Function at MIDUS 3

[1]Executive Function B is characterized by an updating construct, indexed by number series, backward digit span, and SGST tasks

[2]Education was reported on a scale of 1 (no school) to 12 (PhD, EDD, MD, DDS, LLB, LLD, JD or other professional doctorate)

(i.e., EWB) 9 years later. That is, age significantly moderated the relationship between EF and subsequent psychological and social well-being. Importantly, none of the facets of well-being predicted EF 9 years later. Similarly, no evidence was found for a reciprocal relationship between EF and well-being whereby both constructs have a bidirectional influence on each other over time (Rowe & Cosco, 2016). These findings extend the literature and highlight age as a key modulating factor for the longitudinal association between EF and EWB.

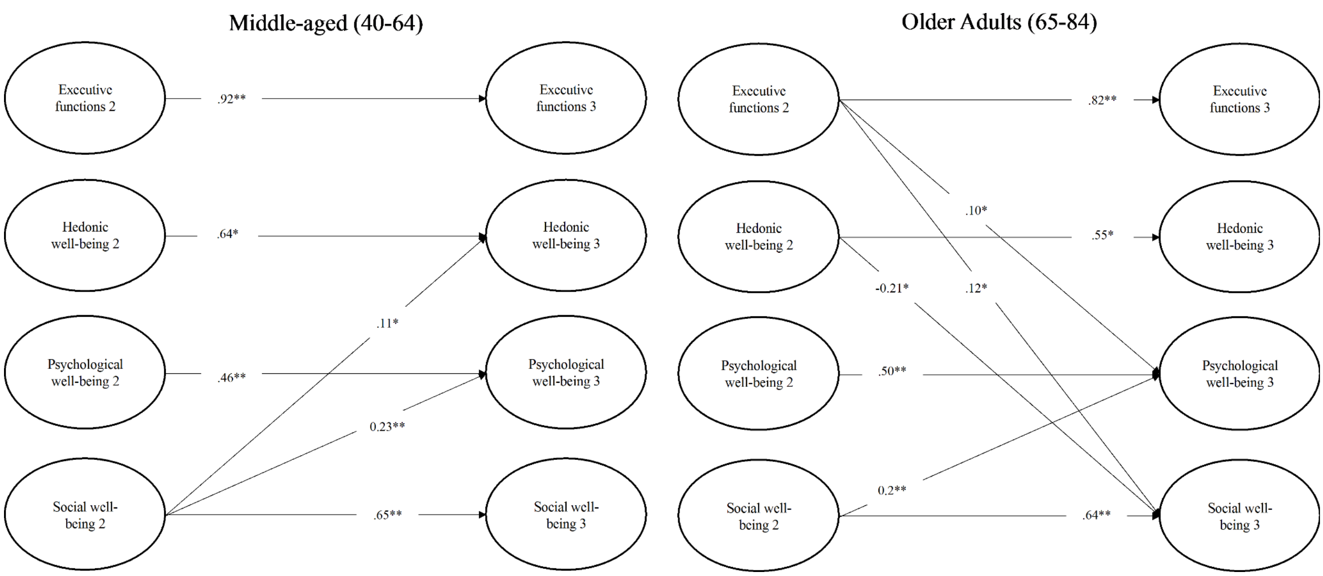

Fig. 1 Parameter estimates of the cross-lagged path model separately for middle-aged and older adults. *Note*. Key structural paths with standardized coefficients from the cross-lagged model are shown, with only significant parameter estimates included. $^{**}p<.01$; $^{*}p<.05$. For full parameter estimates, including covariates, refer to Table 4. For detailed measurement models, see Figures 2, 3, 4, and 5 in the Appendix

Our findings regarding the association between EF and EWB in older adults, as opposed to middle-aged adults, are consistent with previous research. For instance, Allerhand et al. (2014) suggest that rates of change in EF and aspects of EWB, such as sense of control, autonomy, and self-actualization, are higher for older than middle-aged, adults. Similarly, studies indicate that the association between cognition (e.g., processing speed) and control beliefs, which are critical for EWB (Ryff & Singer, 2008), is stronger in older adults than in midlife individuals (Windsor & Anstey, 2008). Together, these findings suggests that cognitive functioning, especially in late adulthood, plays a crucial role in sustaining EWB. This implies that EWB may have stronger cognitive underpinnings in later life and may therefore be more susceptible to age-related cognitive decline as individuals age.

Our study has several notable strengths. We identified the age-dependent association between EF and EWB by conducting multi-group cross-lagged analyses of middle-aged and older adults. It may be debatable whether age should be examined as a continuous or categorical moderator in a single or multi-group model. Drawing on a construct-oriented approach, we adopted a multi-group perspective to investigate bidirectional relationships between EF and facets of well-being in two age groups: middle-aged and older adults. This analysis is informed by the model of third versus fourth age, which distinguishes between different stages of later life—specifically, the period of active and healthy aging versus the period characterized by increased vulnerability and health challenges. Our finding of different cross-lagged parameters according to a critical age threshold supports qualitative differences between middle-aged and older adult age groups. In contrast, when middle-aged and older adults were analyzed as a single group, we observed no significant longitudinal relationships between EF and other facets of well-being ($ps > 0.065$); similar results were obtained for the adjusted model with covariates. This highlights the importance of a multi-group analysis, which proved to be more sensitive in capturing the significant relationship between EF and well-being specifically for older adults.

In addition to these methodological strengths, our study benefits from a large and representative U.S. sample. We controlled for a wide range of confounders, including age, sex, education, household income, subjective health, and personality traits. Using a latent variable approach that incorporates multiple measures of EF, we effectively addressed the task-impurity problem inherent in EF tasks. Furthermore, with respect to the multifaceted construct of well-being, we clarified the bidirectional and longitudinal associations between EF and various facets of well-being across time.

Theoretical implications

Our findings regarding the association between EF and EWB in older adults partially align with the strength and vulnerabilities integration (SAVI) model (Charles, 2010), which posits that age-related cognitive decline reduces individuals' capacity to implement effective emotion regulation strategies, and thereby constrains their ability to have positive emotional experiences. As a result, these limitations can hinder older adults' engagement in meaningful life activities, goal pursuit, sense of purpose, and fulfilment in life (i.e., EWB). Our findings provide longitudinal evidence for this model and underscore the importance of cognitive function in sustaining well-being across psychological and social dimensions. In contrast, the absence of an association between EF and HWB in both middle-aged and older adults diverges from the predictions of the activity restriction model of depressed affect (Williamson et al., 1998), which emphasizes the critical role of cognitive functioning in facilitating activities pertinent to depression, a hedonic aspect of well-being.

Further, our observation of discontinuities in the aging process between middle and late adulthood extends both the SAVI model and the broader literature and underscores the complexity of aging and the nonlinear nature of the association between cognitive functioning and well-being across the lifespan. Given well-documented age-related changes in various aspects of cognitive functioning and their neural architecture (i.e., the prefrontal cortex and hippocampus), our findings suggest that EF may play an increasingly vital role in older adults' efforts to maintain EWB (Lewis et al., 2017). Our results align with the model of the third versus fourth age (Baltes & Smith, 2003), which postulates a qualitative distinction between middle-aged adults and older adults (i.e., young-old, old-old, or oldest-old) and middle-aged adults' better ability to compensate for age-related losses in their pursuit of meaning.

Practical implications

Our findings underscore the importance of attaining high levels of EF and well-being early on, given that these factors at an initial time point positively and strongly predict subsequent EF and well-being 9 years later. Further, our finding that higher levels of EF not only augment later EF levels but also enhance EWB (i.e., psychological and social well-being) highlights the critical importance of EF in promoting healthy aging in late adulthood. These insights suggest that whereas existing interventions (e.g., "Lighten Up," Friedman et al., 2017) aim to directly foster well-being among middle-aged and older adults in the community, it is equally critical that we consider promoting EF through cognitive training to enhance both cognitive functioning and varying aspects of well-being.

For instance, Sahdra et al. (2011) demonstrated that 3 months of meditative training to improve the inhibitory control aspect of EF led to improvements in adaptive functioning (measured by several psychosocial constructs, including psychological well-being). Similarly, an 8-week multi-domain cognitive training program (which incorporated EF tasks) significantly increased psychological well-being in a group of older adults (Pereira-Morales et al., 2018). Furthermore, a 9-week cognitive training program using immersive virtual reality techniques, in which participants engaged in digitally generated physical and cognitive tasks through specialized headsets and controllers, was shown to improve psychological well-being compared with a control group (Kruse et al., 2021). Together, these studies demonstrate the potential of various cognitive training formats to effectively promote well-being and suggest that integrating such approaches into public health initiatives could yield substantial benefits, particularly for older adults.

More importantly, recognizing the qualitative differences between middle-aged and older adults offers valuable direction for policymakers and educators in designing age-specific interventions. For example, older adults often require more support in adapting to retirement and managing health-related issues. Tailoring intervention strategies to emphasize cognitive enhancement and age-related cognitive challenges may facilitate improvements across multiple dimensions of well-being and particularly psychological and social well-being. By adopting an age-specific approach, policymakers and practitioners can offer more targeted and impactful support, and ultimately contribute to positive aging outcomes.

Limitations and future research

Despite its notable strengths, this study has several limitations and raises important questions for future research. First, our findings are based on a 9-year timeframe, which may limit their generalizability to other time intervals. Previous studies with shorter time frames have shown significant relationships between EF and well-being. For example, between- and within-individual associations were found between EF and positive well-being (a composite measure of hedonic and eudaimonic well-being) over 2 years (Allerhand et al., 2014). Specifically, at between-individual level, individuals with higher levels of positive well-being were found to score higher on EF tasks 2 years later. Positive within-individual relationships were also found between EF and well-being (Allerhand et al., 2014). In addition, significant associations between (hedonic) well-being and cognitive functioning have been observed in experimental settings with short time spans (i.e., within a 30-minute period). For instance, several studies found that induced positive mood significantly improved cognitive performance, such as updating or shifting (Yang & Yang, 2014). These results suggest that intraindividual (within-individual) and interindividual (between-individual) relationships between EF and well-being may change across shorter time frames.

Second, our findings may not be generalizable to other age populations. Research has shown that the factor structure of EF varies across different age groups, with patterns of unity (i.e., single factor) in preschoolers (Brydges et al., 2012) and older adults (de Frias et al., 2009) as opposed to more differentiated and diverse structures in adolescents and young adults (Fournier-Vicente et al., 2008). Given this, future research should replicate our findings in other age groups, such as children and adolescents, to examine whether the observed associations hold across the lifespan. Moreover, while our data support a unidimensional construct of EF in line with the dedifferentiation hypothesis (de Frias et al., 2009), future studies should include a broader range of EF tasks to reflect the multidimensional aspects (inhibition, updating, and shifting) of EF. This approach would allow for more nuanced examination of the factor structure of EF in older adults and clarify potentially differential associations between specific EF components and well-being. Also, our findings may not be generalizable to a wide range of cognitive abilities (e.g., reasoning and processing speed) or across different ethnic groups. According to the theory of compound disadvantage, varying relationships between psychological factors and cognitive aging may exist across racial and ethnic groups due to differences in socioeconomic contexts such as educational and income opportunities. Indeed, a recent study showed a significant link between lower HWB (as assessed by depressive symptoms) and poorer episodic memory in African Americans, but not European Americans (Dixon et al., 2021).

Third, although we failed to find any significant longitudinal associations between EF and well-being for middle-aged adults, EF could still *indirectly* influence well-being via biopsychosocial mechanisms. Health constraints, coping strategies, and lifestyle may mediate the relationships between EF and well-being. Specifically, the association between EF and life satisfaction (cognitive well-being) was found to be mediated by active coping and behavioral disengagement (Oh & Yang, 2022). Thus, further research is needed to explore the temporal pathways of these potential mediators and their effects on EF and various facets of well-being.

Lastly, our dataset includes only two instances of repeated measurement. Although the traditional ACLM is appropriate for two-wave data, this prevents us from distinguishing within- and between-persons relationships between EF and well-being. Future research should expand beyond the two waves and explore the dynamic relationships between EF and well-being over shorter and longer time frames in middle-aged and older adults. Employing a more recent modeling method, such as the random-intercept autoregressive cross-lagged panel model—which requires a minimum of three waves—would allow for more accurate understanding of these relationships (Hamaker et al., 2015). Also, while cross-lagged regression parameters in longitudinal data are often used to infer causal relationships, establishing true causality requires satisfying critical criteria—temporal precedence, covariation, non-spuriousness, and strong theoretical support—which are typically achieved through experimental research design (Moreno & Martínez, 2008). We were unable to establish causality due to several limitations, including the lack of consistent covariation patterns over time, the need to control for other potential confounding variables, and the absence of a robust theoretical framework based on empirical evidence to support causal inference.

Conclusion

Our findings have important conceptual implications for the relation between cognition and well-being as well as healthy aging. Executive functioning is deemed to be a crucial cognitive capacity and resource for sustaining well-being in old age, because it enables an individual to continue engaging in both instrumental and meaningful activities (Rowe & Cosco, 2016) that, in turn, afford a sense of purpose in life (i.e., psychological well-being; Toh & Yang, 2024). Moreover, executive functioning helps an individual navigate their social environment and overcome social challenges (i.e., social well-being). In essence, our study provides a critical glimpse into the empirical relationships between EF and a multifaceted construct of well-being (i.e., HWB and EWB as distinct indicators of successful aging) that are qualitatively moderated by discontinuous aging processes (e.g., middle age vs. older adulthood).

Appendix

Table 7 Correlations between key variables

Variables	M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. MIDUS 2 Affective well-being	4.11	0.52	—													
2. MIDUS 2 Life satisfaction	7.84	1.08	0.54**	—												
3. MIDUS 2 Eudaimonic well-being	5.57	0.82	0.67**	0.52**	—											
4. MIDUS 2 Social well-being	4.82	0.85	0.43**	0.41**	0.59**	—										
5. MIDUS 2 Executive functions	0.18	0.96	0	0.02*	0.08**	0.15**	—									
6. MIDUS 3 Affective well-being	4.82	0.85	0.6**	0.37**	0.48**	0.35**	0.02*	—								
7. MIDUS 3 Life satisfaction	4.82	0.85	0.38**	0.59**	0.37**	0.36**	0.05*	0.52**	—							
8. MIDUS 3 Eudaimonic well-being	4.82	0.85	0.51**	0.4**	0.73**	0.54**	0.12**	0.64**	0.53**	—						
9. MIDUS 3 Social well-being	4.82	0.85	0.32**	0.31**	0.47**	0.65**	0.16**	0.37**	0.39**	0.58**	—					
10. MIDUS 3 Executive functions	4.82	0.85	-0.02*	-0.02	0.06*	0.15**	0.72**	0.07**	0.03*	0.15**	0.19**	—				
11. Age 2	56.34	10.29	0.23**	0.27**	0.13**	0.06**	-0.34**	0.11**	0.15**	0.04*	-0.02*	-0.45**	—			
12. Education 2	7.43	2.5	0.05*	0.08**	0.15**	0.26**	0.38**	0.06**	0.12**	0.18**	0.31**	0.36**	-0.12**	—		
13. MIDUS 2 Health	2.34	0.95	-0.32**	-0.36**	-0.29**	-0.24**	-0.23**	-0.27**	-0.31**	-0.28**	-0.25**	-0.25**	0.07**	-0.24**	—	
15. MIDUS 2 Income	75.17	61.2	0.05*	0.09**	0.13**	0.15**	0.3**	0.1**	0.13**	0.19**	0.2**	0.31**	-0.28**	0.36**	-0.19**	—

Note. Sex (1 = Female, 2 = Male)

Education is measured from 1 (No school) to 12 (Doctoral or other professional degree)

Income includes wages, salaries, stipends from all jobs; measurement unit = $1,000,000

**p <.01, *p <.05

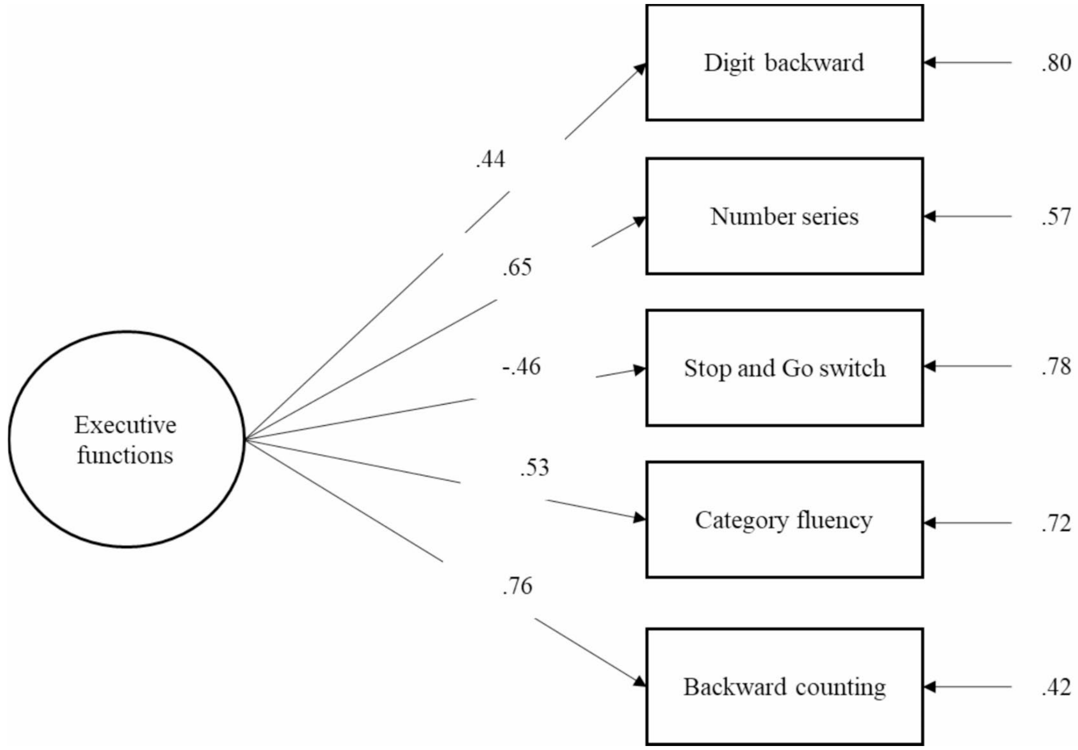

Fig. 2 Measurement model of executive functions

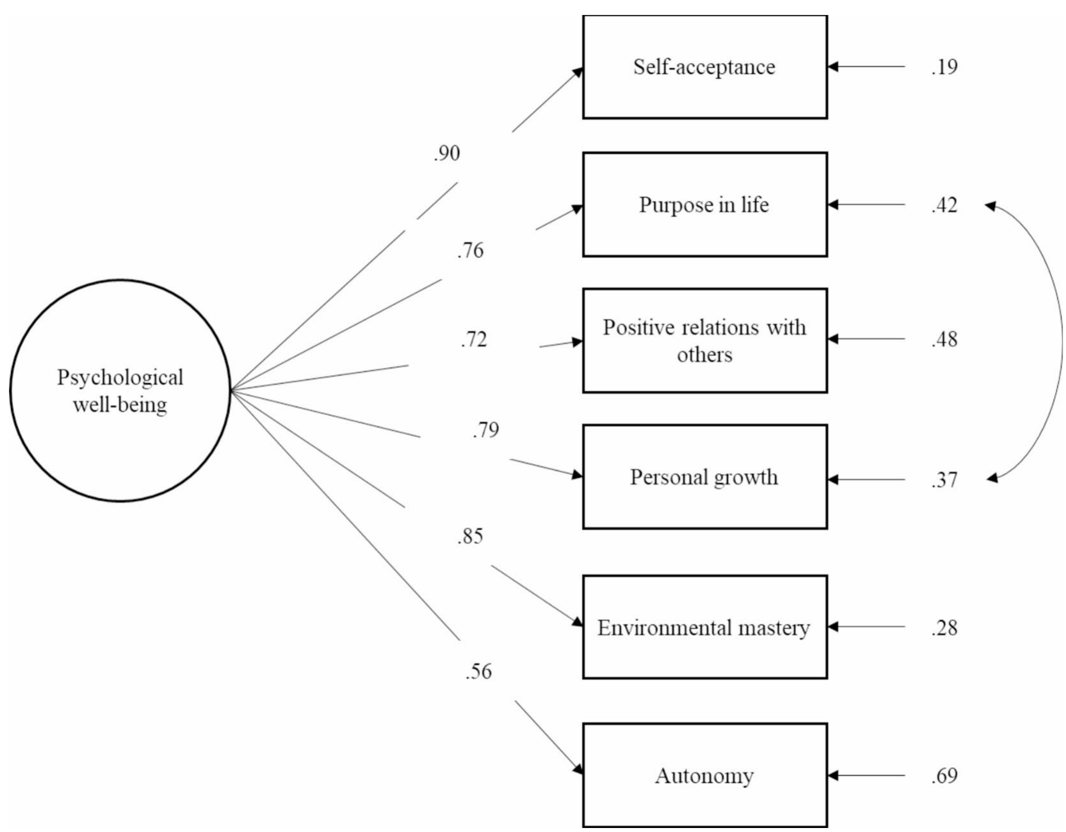

Fig. 3 Measurement model of psychological well-being

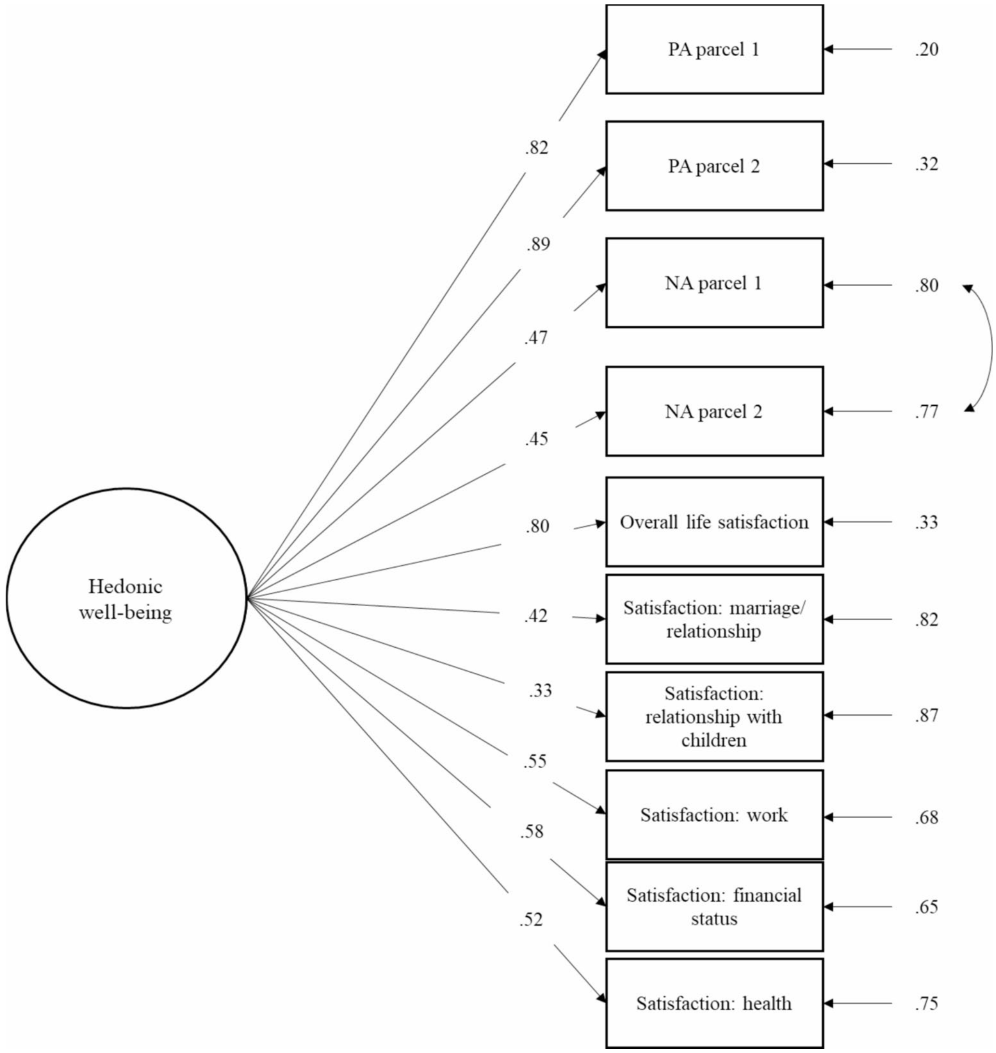

Fig. 4 Measurement model of hedonic well-being

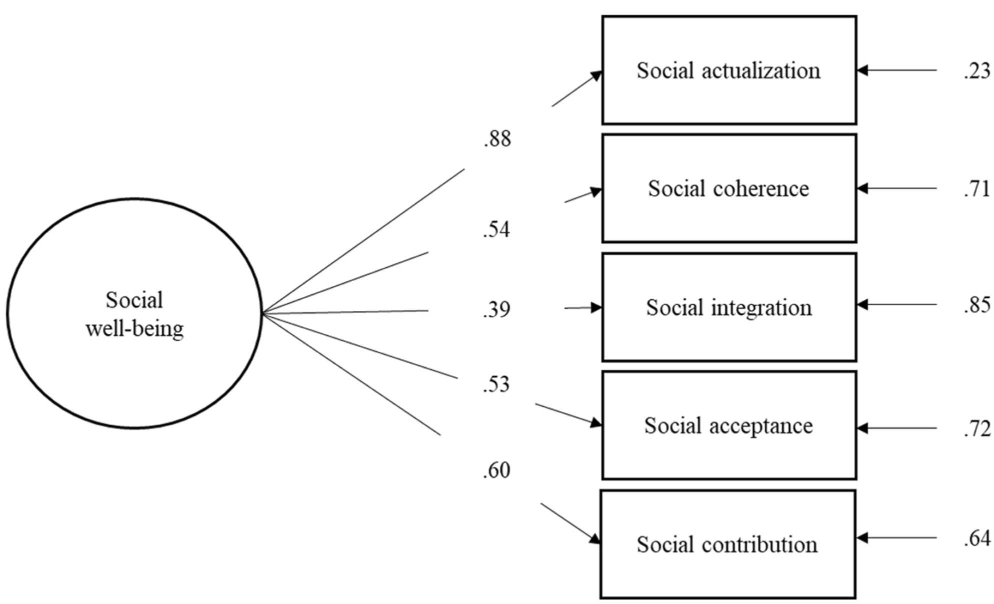

Fig. 5 Measurement model of social well-being

Acknowledgements MIDUS 2 and MIDUS 3 research was supported by grants from the National Institute on Aging (P01AG020166, R37AG027343). MIDUS data collection was conducted in accordance with the Declaration of Helsinki and approved by the Education and Social/Behavioral Sciences and the Health Sciences Institutional Review Boards of the University of Wisconsin-Madison.

Data availability Data are from the Midlife in the United States project (MIDUS; midus.wisc.edu).

Declarations

Conflict of interest No potential conflict of interest was reported by the author(s).

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