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Change in Cognitive Performance From Midlife Into Old Age: Findings from the Midlife in the United States (MIDUS) Study

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Abstract

Objectives: A substantial body of research has documented age-related declines in cognitive abilities among adults over 60, yet there is much less known about changes in cognitive abilities during midlife. The goal was to examine longitudinal changes in multiple cognitive domains from early midlife through old age in a large national sample, the Midlife in the United States (MIDUS) study. **Methods:** The Brief Test of Adult Cognition by Telephone (BTACT) was administered on two occasions (MIDUS 2, MIDUS 3), an average of 9 years apart. At MIDUS 3, those with the cognitive assessment ($N = 2518$) ranged in age from 42 to 92 years ($M = 64.30$; $SD = 11.20$) and had a mean education of 14.68 years ($SD = 2.63$). The BTACT includes assessment of key aging-sensitive cognitive domains: immediate and delayed free recall, number series, category fluency, backward digit span, processing speed, and reaction time for attention switching and inhibitory control, which comprise two factors: episodic memory and executive functioning. **Results:** As predicted, all cognitive subtests and factors showed very small but significant declines over 9 years, with differences in the timing and extent of change. Processing speed showed the earliest and steepest decrements. Those with higher educational attainment scored better on all tests except reaction time. Men had better executive functioning and women performed better on episodic memory. **Conclusions:** Examining cognitive changes in midlife provides opportunities for early detection of cognitive impairments and possibilities for preventative interventions. (*JINS*, 2018, *24*, 805–820)

Keywords: Middle aged, Cognitive aging, Sex differences, Educational status, Longitudinal studies, Cognitive function

INTRODUCTION

Compromised cognitive functioning in later life has been identified as a risk factor for increased morbidity and mortality (Schaie, 1996; Swan, Carmelli, & LaRue, 1995). Although a good deal is known about cognition in old age in comparison to young adults (especially college students), much less is known about cognition in midlife (Bielak, Hughes, Small, & Dixon, 2007; Salthouse, 2010; Soederberg Miller & Lachman, 2000; Sternberg, Grigorenko, & Oh, 2001; Willis & Boron, 2008; Willis & Schaie, 1999, 2006). Further understanding of the nature of midlife cognition can provide insights into the emergence of cognitive decline (Agrigoroaei & Lachman, 2011). The present study used data from the Midlife in the United States (MIDUS, Brim, Ryff, & Kessler, 2004), a longitudinal study of adults across a wide age range (ages 25 to 95) from early midlife through old age, to examine changes over 9 years in multiple cognitive domains using a brief telephone battery. In addition, we examined whether there are differences in change as a function of age, sex, and education.

There is a surprising paucity of national data in the United States (U.S.) on cognitive functioning across the adult lifespan, from young adulthood through mid- and later life. Many of the previous studies have specialized, clinical, or convenience samples or are based on local samples in the United States or Canada (e.g., Framingham Heart Study, Normative Aging Study, Seattle Longitudinal Study, Victoria Longitudinal Study) and Europe (e.g., Swedish Twin Study, Berlin Aging, Bonn Longitudinal Study). Many major epidemiological surveys such as the Longitudinal Survey on Aging (Miller, Rejeski, Reboussin, Ten Have, & Ettinger, 2000) do not measure cognitive function or only include a dementia screener (see Lachman & Tun, 2008).

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One exception is the U.S. Health and Retirement Study (HRS), a survey of more than 20,000 adults ages 50 and above (Herzog & Wallace, 1997; McArdle, 2011), which included a measure of immediate and delayed recall (e.g., Fisher et al., 2014). However, many of the findings from the HRS longitudinal cognitive data are derived from a limited set of items from dementia screeners that are not sensitive to differences in normal aging, especially in midlife. Recently, the HRS has expanded its cognitive battery to include more age sensitive measures such as inductive reasoning (e.g., number series) and category fluency (e.g., animal naming), domains also present in the MIDUS study (McArdle, 2011); however, the HRS study does not include adults under the age of 50. Thus, no large-scale U.S. national data sets with multiple aspects of cognition are available with younger and middle-aged men and women in their 30s and 40s, and continuing through older adulthood (Piccinin & Hofer, 2008).

Cognitive Aging

In the past two decades a substantial body of research has documented age-related declines in cognitive abilities among adults over 60 (e.g., Craik & Salthouse, 2008; Hofer & Alwin, 2008; Karlamangla et al., 2009; Salthouse, 1996; Schaie, 1994; Hultsch, Hertzon, & Dixon 1990). Much of this cognitive aging literature is based on relatively small samples of college students and older adult volunteers matched for educational level and brought into university labs, whereas middle-aged adults or those without some college education are included less often (Lachman, 2015). Other cross sectional studies using volunteer samples have examined cognitive abilities across adulthood, showing the most pronounced age differences for processing-intensive abilities (e.g., speed of processing, working memory, executive function) beginning as early as the 20s. (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Park et al., 2002).

There are several longitudinal studies, largely conducted in Europe and Australia (e.g., Whitehall in England, Betula and Twin Studies in Sweden, Interdisciplinary Study on Adult Development in Germany, and the Path Study in Australia) that have included participants under the age of 50 with a broader educational range. These studies provide evidence that there are declines in cognitive functioning as early as the mid-40s (Anstey, Sargent-Cox, Garde, Cherbuin, & Butterworth, 2014; Brunner et al., 2017; Davis et al., 2017; Rönnlund & Nilsson, 2006; Singh-Manoux et al., 2012; Zimprich & Mascherek, 2010). Findings on age differences from cross-sectional, normative studies of cognitive batteries such as the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1997), are consistent with these longitudinal findings (Ryan, Sattler, & Lopez, 2000).

In general, there is consistent evidence of age-related declines in cognition, yet there are wide individual differences and variations in the timing and extent of cognitive decline. The differences arise in part due to the age range of the participants, the length of the time intervals between the occasions of measurement, as well as the particular cognitive domains studied. In summary, across key longitudinal studies of cognitive aging, the evidence shows that some domains begin to show declines earlier than others (e.g., speeded measures), and there is some variation in when cognitive change is found to begin. The current study is the first to examine longitudinal cognitive changes on a wide range of domains including adults under the age of 50 and into old age and using a telephone battery in a national sample in the United States.

Differences by Education and Sex

In addition to age differences, there is evidence for differences in cognitive functioning by education (the most commonly used marker of socioeconomic status in cognitive aging research). Those with lower educational attainment generally show poorer cognitive functioning (Cagney & Lauderdale, 2002; Lee, Kawachi, Berkman, & Grodstein, 2003; Lyketsos, Chen, & Anthony, 1999; Rabbitt, Donlan, Watson, McInnes, & Bent, 1995; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003; Turrell et al., 2002), but there are inconsistent findings in relation to cognitive change (Wilson et al., 2009). Low educational attainment has been well established as a major risk factor for dementia in older adults (Evans et al., 1993; Ganguli et al., 1991; Hatch, Feinstein, Link, Wadsworth, & Richards, 2007; Letenneur et al., 2000; Murden, McRae, Kaner, & Bucknam, 1991; Uhlmann & Larson, 1991; Wiederholt et al., 1993; Willis, 1996). However, there is mixed evidence as to whether education is associated with the timing and extent of cognitive declines in normal aging (Stern, 2002, 2009; Zahodne et al., 2011).

Sex differences have also been examined in relation to cognitive aging. Although women perform better than men on most memory tasks, men outperform women on some tests of memory especially when the test contains an analytic (Caselli et al., 2015) or spatial component (Fastenau, Denburg, & Hufford, 1999; Gallagher & Burke, 2007). Although there is limited evidence for differential cognitive changes by gender, some work has demonstrated a steeper decline of cognitive function for women (Karlamangla et al., 2009). Therefore, the question of whether men and women show differential trajectories of change in midlife and beyond remains of interest.

Current Study

The present study can enrich our knowledge about changes in cognitive abilities beginning early in midlife. Cognitive aging is often studied with small samples in the lab or clinic with a restricted range of education and age. The MIDUS project provides a rich opportunity to examine age differences in a more diverse national sample, using a brief battery that can be administered over the telephone, and includes measures of speed and reaction time. The availability of the MIDUS 3 longitudinal data, using the Brief Test of Adult Cognition by Telephone (BTACT, Lachman, Agrigoroaei, Tun, & Weaver, 2014), enables us for the first time to look at changes in cognition during the transitions into midlife and from midlife to old age in a large, age-heterogeneous U.S. national sample with a wide range of educational level.

As the measures included in the BTACT are markers of cognitive mechanics (fluid intelligence) rather than pragmatics or crystallized intelligence (Baltes, Lindenberger, & Staudinger, 2006), and are sensitive to aging-related changes, we predicted that there would be significant declines on average for all cognitive measures over the 9 year period of study. We expected the declines would be consistent with the cross-sectional age differences found at MIDUS 2 (Lachman et al., 2014); that is the declines would begin by 50 years of age, the amount of the decrement would become larger with age, and would be most pronounced for measures of processing speed and the least pronounced for backward digit span. Based on the previous cross-sectional findings, we predicted there would be sex and education differences in level, but not in the amount of change for these variables.

METHODS

Participants

The current study focused on the participants from the second and third waves of the MIDUS national longitudinal study who completed the cognitive assessment (the BTACT was not administered at MIDUS 1). The study was approved by the institutional review boards involved with MIDUS. The initial MIDUS 1 probability sample ($N = 7100$) was generated in 1995–1996 through random digit dialing of U.S. households having at least one telephone in the contiguous 48 states, stratified by age with an oversample of those between 40 and 60 years of age. The original participants ranged in age from 24 to 75 years ($M = 46.40$; $SD = 13.00$) with a mean education level of 13.21 years, and 51.7% women; minorities were underrepresented with Whites comprising 90.7% of the sample (for more information, see Brim et al., 2004).

The second occasion of measurement, MIDUS 2, was 9 years later, and 75% of the original sample, adjusted for mortality ($N = 4955$), was retested (Radler & Ryff, 2010). At MIDUS 2, participants ranged in age from 32 to 84 years ($M = 55.36$; $SD = 12.40$) and had a mean education level of 14.24 years ($SD = 2.60$). Women made up 53.8% of the sample, and Whites were 90.1% of the sample. The mean self-rated health on a 5-point scale (1 = poor, 5 = excellent) was 3.53 ($SD = 1.02$). As is typically found, those who participated at the second wave showed some differences on MIDUS 1 variables compared with those who dropped out of the study (Radler & Ryff, 2010). Compared to the dropouts, longitudinal participants were more highly educated, $t(6757) = 12.48$, $p < .001$, (Mean years of education 14.06 *vs*. 13.21); were more likely to be women, (53.8% *vs*. 48.3%), $\chi^2(1) = 17.49$, $p < .001$; and had higher self-rated health, $t(6759) = 10.42$, $p < .001$, (Mean = 3.61 *vs*. 3.33). Dropouts were more likely to be non-white (16%) compared to the longitudinal participants (7% non-white), $\chi^2(1) = 112.22$, $p < .001$.

MIDUS 3 was conducted 9.12 years later on average ($SD = .53$). Of the sample from MIDUS 2, 76.9% of those eligible ($N = 3294$) were reinterviewed. At MIDUS 3, those with the cognitive assessment ($N = 2518$) ranged in age from 42 to 92 years ($M = 64.30$; $SD = 11.20$) and had a mean education level of 14.68 years ($SD = 2.63$). Women made up 55.3% of the sample, the mean self-rated health was 3.46 ($SD = 1.01$), and whites made up 90.4% of the sample.

Measures and Procedure

Demographics

Age, sex, and education information was obtained in the telephone interview. Age was used as a continuous variable in analyses. Education was converted into the number of years of education.

Health

Health was assessed in the mail-back self-administered questionnaire. Participants rated their physical health (Idler & Benyamini, 1997) on a 5-point scale ranging from 1 (poor) to 5 (excellent).

The MIDUS Cognitive Battery: The Brief Test of Adult Cognition by Telephone

The Brief Test of Adult Cognition by Telephone (BTACT) (Lachman et al., 2014) assesses key cognitive domains that are of theoretical significance for cognitive aging, and was designed for telephone administration with a wide range of ages and levels of educational attainment (Lachman & Tun, 2008; Tun & Lachman, 2006). The BTACT battery includes a combination of existing and new subtests, and is a reliable, valid measure of cognition, despite its brief length (for more information, see Lachman et al., 2014). Seven cognitive tests are included in the BTACT (Lachman et al., 2014). This included two measures of episodic memory (immediate and delayed free recall of 15 words), inductive reasoning (number series; completing a pattern in a series of five numbers), category verbal fluency (the number of words produced from the category of animals in 60 s), working memory span (backward digit span; the highest span achieved in repeating strings of digits in reverse order), processing speed (30 Second And Counting Task, or 30-SACT; the number of digits produced by counting backward from 100 in 30 s), and attention switching and inhibitory control (Stop and Go Switch Task, SGST; Tun & Lachman, 2008). For the SGST, reaction times were calculated with the mean of switch and nonswitch trials median latencies on a task requiring alternating between the “normal” condition (i.e., respond “Go” to the stimulus “Green” and “Stop” to the stimulus “Red”) and the “reverse” condition (i.e., respond “Stop” to the stimulus “Green” and “Go” to the stimulus “Red”).

Given the relatively high rate of cell phone use at Time 3 (25.6% used cell phones), it was necessary to correct for the typical delay in voice transmission when compared to landlines. Immediately before and after the SGST, all participants completed a metronome task where they were asked to count in cadence with a digital metronome. A metronome was set at 1s intervals, and the participants were instructed to listen to

Table 1. Comparison of MIDUS 3 longitudinal participants and dropouts on demographic variables, health, and cognitive scores at MIDUS 2 ($N = 4206$)

	Longitudinal		Dropout	
	Mean (*SD*)	Range	Mean (*SD*)	Range
Age*	55.20 (11.19)	33–83	57.18 (13.77)	28–84
Sex (women)	55.3%	—	52.4%	—
Education (years)*	14.69 (2.61)	6–20	13.83 (2.57)	6–20
Race (White)*	93.1%		90%	
Self-rated health*	3.68 (0.93)	1–5	3.34 (1.09)	1–5
Immediate word list recall*	7.00 (2.19)	0–15	6.32 (2.37)	0–15
Delayed word list recall*	4.69 (2.51)	0–14	4.01 (2.73)	0–14
Number series*	2.51 (1.50)	0–5	1.92 (1.47)	0–5
Category fluency*	19.73 (6.02)	1–42	17.36 (6.11)	0–42
Backward digit span*	5.09 (1.46)	0–8	4.88 (1.57)	0–8
30-SACT backward counting*	38.66 (11.20)	−2–90	35.15 (11.45)	2–100
SGST latency*	1.07 (.23)	.61–3.77	1.13 (.34)	.22–7.36
Episodic memory*	0.12 (.95)	−2.42–3.83	−0.18 (1.04)	−3.07–3.63
Executive functioning*	0.17 (.95)	−3.28–3.42	−0.25 (1.01)	−4.74–2.68

Note. An asterisk indicates significant differences between longitudinal and dropout participants at $p < .001$.

get the beat, and then to count out loud from 1 to 10 at the exact time as the metronome clicks sounded. The delay between the click and the moment the participant responded was measured for each participant, and a median latency value was calculated for the pre- and post-test block. The first two trials of each block were discarded as practice trials. In some cases, participants were able to match the cadence of the metronome exactly. These cases were deemed to have no delay, and were given a latency score of 0. Once the median latency was calculated, the pre- and post-test blocks were averaged together. This average was then subtracted from the participant's raw reaction time to obtain a corrected reaction time. Only participants who used cell phones were corrected in this way.

As is typical in longitudinal studies, those who participated at the third wave showed some differences on MIDUS 2 variables compared with those who dropped out of the study (see Table 1). Compared to dropouts, longitudinal participants performed significantly better on all cognitive tests and factors at MIDUS 2 (see Table 1 for means).

DATA ANALYSIS AND RESULTS

Descriptive Results

Correlations of age, sex, education with all cognitive measures are shown in Table 2. As expected, at both occasions, better test performance was associated with younger age and higher education. Women performed better on the episodic memory subtests and factor, and men did better on the executive functioning factor and all other subtests except backward digit span.

All cognitive tests demonstrated relatively high test–retest correlations with an average of .59 and a range of .38 to .85 (see Table 3). Table 4 presents the mean scores for all tests at MIDUS 2 and MIDUS 3.

Longitudinal Measurement Invariance

Separate confirmatory factor analyses (CFA) at MIDUS 2 and MIDUS 3 were conducted and confirmed that the BTACT captures two factors, episodic memory (EM) and executive functioning (EF), consistent with previous literature (Farias et al., 2013; Jurado & Rosselli, 2007; Lachman et al., 2014; Lachman, Agrigoroaei, Murphy, & Tun, 2010; Royall et al., 2002). For longitudinal analysis, however, it is important to ensure that the same construct is being measured over time because otherwise, the changes may reflect differences in the factor structure rather than changes in the same construct (Horn & McArdle, 1992).

To assess factorial invariance of the BTACT at two occasions (MIDUS 2, MIDUS 3), we fit a series of CFA models with increasing invariance constraints: configural invariance (same conceptual factor structure), weak invariance (same factor loading structure), strong invariance (same factor loadings and same intercepts), and strict invariance (same factor loadings, same intercepts, and same residual variances; Isiordia & Ferrer, 2016; Vandenberg & Lance, 2000). The CFA models were estimated using full information maximum likelihood estimation with Mplus (Muthén & Muthén, 2008). The SGST latency variable was multiplied by (–1) so that higher scores would correspond to faster reaction times. Based on the log-likelihood tests ($p < .05$), we found that a weak invariance model was best supported by the data, $\chi^2(72) = 548.43$, $p < .01$, root mean square error of approximation (RMSEA) = 0.040, comparative fit index (CFI) = 0.967, Tucker Lewis Index (TLI) = 0.959, although the more stringent models also fit reasonably well (see Table 5 and Supplementary Table S1). Factor

Table 2. Correlations for all variables at MIDUS 2 and MIDUS 3

	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	—											
2. Sex	−.008 (.000)	—										
3. Education	−.15* (−.15*)	−.10* (−.12*)	—									
4. Health	−.17* (−.10*)	−.01 (−.03)	.26* (.24*)	—								
5. Immediate word list recall	−.32* (−.37*)	.21* (.22*)	.21* (.21*)	.19* (.18*)	—							
6. Delayed word list recall	−.32* (−.35*)	.21* (.24*)	.19* (.17*)	.16* (.16*)	.79* (.80*)	—						
7. Number series	−.26* (−.35*)	−.11* (−.14*)	.41* (.41*)	.23* (.19*)	.29* (.29*)	.26* (.23*)	—					
8. Category fluency	−.31* (−.38*)	−.07* (−.03)	.35* (.32*)	.20* (.18*)	.31* (.34*)	.26* (.27*)	.38* (.39*)	—				
9. Backward digit span	−.17* (−.23*)	.03 (.01)	.20* (.23*)	.14* (.14*)	.35* (.34*)	.33* (.31*)	.34* (.37*)	.21* (.25*)	—			
10. 30-SACT backward counting	−.43* (−.45*)	−.14* (−.14*)	.29* (.30*)	.25* (.22*)	.29* (.32*)	.25* (.27*)	.48* (.53*)	.42* (.44*)	.30* (.36*)	—		
11. SGST latency	.31* (.24*)	.10* (.08*)	−.17* (−.11*)	−.20* (−.12*)	−.23* (−.19*)	−.19* (−.15*)	−.29* (−.24*)	−.31* (−.25*)	−.18* (−.17*)	−.45* (−.36*)	—	
12. Episodic memory	−.34* (−.39*)	.22* (.24*)	.21* (.20*)	.18* (.19*)	.95* (.95*)	.95* (.95*)	.29* (.28*)	.31* (.33*)	.35* (.35*)	.29* (.32*)	−.23* (−.19*)	—
13. Executive functioning	−.43* (−.47*)	−.11* (−.11*)	.41* (.38*)	.30* (.24*)	.43* (.42*)	.38* (.34*)	.73* (.71*)	.68* (.65*)	.60* (.60*)	.78* (.77*)	−.59* (−.64*)	.43* (.41*)

Note. An asterisk indicates a significant correlation at $p < .001$. For Sex, men = 1, women = 2. MIDUS 2 $N = 4206$; MIDUS 3 (in parentheses) $N = 2518$.

Table 3. Stability correlations between MIDUS 2 and MIDUS 3 cognitive measures ($N = 2516$)

Cognitive measure	MIDUS 2 to MIDUS 3 correlation
Immediate word list recall	.48*
Delayed word list recall	.52*
Number series	.64*
Category fluency	.64*
Backward digit span	.47*
30-SACT backward counting	.85*
SGST latency	.38*
Episodic memory	.54*
Executive functioning	.76*

Note. An asterisk indicates significant correlations at $p < .001$.

scores were computed as the mean of the standardized test scores loading on each factor, based on the MIDUS 2 means and standard deviations for both occasions.

Longitudinal Analyses for the BTACT Subtests and Factors

We examined cognitive change over the 9 years and differences by age, sex, and education. To investigate changes in the seven subtests over time, we applied a linear mixed effects model (LME), which has also been described as a multilevel or hierarchical model (Ghisletta, Rabbitt, Lunn, & Lindenberger, 2012; MacCallum, Kim, Malarkey, & Kiecolt-Glaser, 1997). LME provides a flexible and powerful statistical modeling framework for the analysis of longitudinal data with missing observations (Fitzmaurice, Laird, & Ware, 2011; Verbeke & Molenberghs, 2000). All observations at MIDUS 2 and MIDUS 3 were included in these analyses.

We specified a multivariate linear mixed effects model to the seven subtests. Denote Y_{ikt} be the response for subject i $(=1,\ldots,4206)$ to subtest k $(=1, \ldots,7)$ at time t $(=1,2)$. The multivariate linear mixed effects model for Y_{ikt} was specified as follows:

$$Y_{ikt}=\beta_{0k}+\beta_{1k}\,Time\,2+u_{0ik}+u_{1ik}\,Time\,2+\epsilon_{ikt}, \qquad [1]$$

where β_{0k} is the subtest specific intercept representing the mean score of the k-th subtest at the first occasion (MIDUS 2), and β_{1k} is the subtest specific slope representing the mean score change between the two occasions (MIDUS 3-MIDUS 2) in the k-th subtest. The subtest specific random effects for the intercept and the change, $(u_{0ik},u_{1ik})'$ were assumed to follow a bivariate normal distribution $(u_{0ik}, u_{1ik})' \sim BN(\mathbf{0},\Sigma)$, where Σ is a 2×2 covariance matrix. The level-1 subtest specific residual ε_{ikt} was assumed to follow a normal distribution, $\varepsilon_{ikt} \sim N(0,\sigma_k^2)$. For computational ease, we assume homoscedasticity for the level-1 and level-2 random effects terms. We additionally considered a bivariate linear mixed effects model for the EM and EF factors. The model formulation is equivalent to Eq. [1]. The difference is that the subscript k indicates the EM factor when $k = 1$ and the EF factor when $k = 2$.

We also incorporated age, sex, and education years in the model to investigate the effects of those covariates on the intercept (mean score at MIDUS 2) and the slope (mean score difference, MIDUS 3-MIDUS 2). In addition, we further examined the interactions to test whether the effects of age on the change (difference scores) would be moderated by sex and education years. Note that age and education years are continuous variables and sex is a categorical variable (that takes value 0 for male and 1 for female). Age and education years were mean-centered so that the intercepts can be interpreted as the average scores.

As the MIDUS sample includes some siblings, we tested whether including within-family dependence (by including an additional random effects term for family) would change the results. We confirmed that for this test, the estimates of the key covariates and their significance remained the same. Hence, all analysis excluded the family random effects term from the model. In addition, for all models, we conducted a sensitivity analysis by including self-reported health as a covariate. As the results did not change, we report only the results without the health covariate. The multivariate and bivariate linear mixed effects models were estimated using full information maximum likelihood estimation with the R package lme4 (Bates, Mächler, Bolker, & Walker, 2015).

Table 4. Means and standard deviations for cognitive subtests and factors at MIDUS 2 and MIDUS 3

	MIDUS 2[a]			MIDUS 3[b]		
	Mean (*SD*)	Range	*N*	Mean (*SD*)	Range	*N*
Immediate word list recall	6.73 (2.29)	0–15	4189	6.71 (2.36)	0–15	2509
Delayed word list recall	4.42 (2.62)	0–14	3996	4.39 (2.67)	0–14	2389
Number series	2.27 (1.52)	0–5	4166	2.34 (1.55)	0–5	2451
Category fluency	18.78 (6.16)	0–42	4192	18.84 (6.06)	0–40	2513
Backward digit span	5.00 (1.51)	0–8	4193	4.98 (1.47)	0–8	2516
30-SACT backward counting	37.26 (11.43)	−2–100	4175	36.34 (11.46)	− 2–90	2492
SGST latency	1.09 (0.28)	0.22–7.36	4018	1.27 (0.39)	0.42–7.67	2416
Episodic memory	0.00 (1.00)	− 3.07–3.83	4189	− 0.02 (1.03)	− 3.07–3.83	2512
Executive functioning	0.00 (1.00)	− 4.74–3.42	4198	− 0.24 (1.08)	− 5.28–2.97	2518

[a] Full sample.
[b] Longitudinal sample.

Table 5. Parameters from confirmatory factor analysis with weak measurement invariance

Item or factor	Episodic memory MIDUS 2	Episodic memory MIDUS 3	Executive functioning MIDUS 2	Executive functioning MIDUS 3
Standardized factor loadings				
Immediate word list recall	0.94	0.95		
Delayed word list recall	0.84	0.85		
Number series			0.56	0.50
Category fluency			0.57	0.60
Backward digit span			0.44	0.48
30-SACT backward counting			0.75	0.77
SGST latency			0.59	0.39
Factor correlations				
Episodic memory MIDUS 2	—			
Episodic memory MIDUS 3	0.62	—		
Executive functioning MIDUS 2	0.49	0.46	—	
Executive functioning MIDUS 3	0.46	0.53	0.94	—

Note. Parameters are all statistically significant at $p < .001$.

For the multivariate analysis for the seven subtests, we first fit Model (1) assuming a global (shared) set of regression coefficients across the seven subtests. The SGST latency variable was multiplied by (–1) so that the direction is consistent with the other subtests, that is, high scores indicate better (faster) performance, and decreases over time would indicate slowing. The effect size measure δ indicates delta total, where total is the total of the variance components (Hedges, 2007). The δ can be interpreted similar to Cohen's *d*. The main effect for age (on the intercept) was –0.09 ($SE = 0.003$, 95% confidence interval (CI) [−0.10, –0.09], $\delta = -0.028$), for sex (female) was –0.16 ($SE = 0.07$, 95% CI [−0.30, –0.01], $\delta = -0.031$), and for education years was 0.34 ($SE = 0.01$, 95% CI [0.31, 0.36], $\delta = 0.072$). These effects were all significant at the .01 level, but only age and education effects were significant at the .001 level. In terms of effect size δ, they all indicated very small effects (Sawilowsky, 2009).

For cognitive change, the effect of age was –0.03 ($SE = 0.004$, 95% CI [−0.04, −0.02], $\delta = -0.006$) and was significant at the 0.001 level, with a very small effect in terms of δ, while the effects of sex and education years on change were not significant. In addition, the interactions between the three covariates on change were not significant. The variance for the random intercept and slope (change) were estimated as 2.29 and 2.55, respectively. The correlation between the random intercept and slope was close to 1.00, meaning that the two random effect terms (intercept and change) were not differentiable in this analysis. The level-1 residual variance was estimated to be 21.83.

For the SGST, we examined whether the results were affected by including cell phones with the corrected scores. We added telephone type (cell phone *vs.* landline) as a variable in our model to see if there was an effect and we examined interactions of telephone type with age, education, and sex. There are no significant differences in the effects (of age, sex, education) between landline and cell users. We examined the effects of telephone type for the reaction time test (SGST), which is the only test that is affected by cell phone use because it relies on timing. We found there were no differences in the results. Thus, we included cell phone users in all analyses.

For the bivariate model for the EM and EF factor scores, the main effect for age (on the intercept) was –0.016 ($SE = 0.002$, 95% CI [−0.02, –0.01], $\delta = -0.016$), for sex (female) was 0.13 ($SE = 0.04$, 95% CI [−0.05, 0.22], $\delta = 0.128$), and for education years was 0.11 ($SE = 0.01$, 95% CI [0.10, 0.13], $\delta = 0.109$). The effect of age on cognitive change was –0.011 ($SE = 0.001$, 95% CI [−0.014, –0.009], $\delta = -0.011$). These small effects were all significant at the 0.01 level. The effects of sex, education, as well as the interaction effects between the three covariates on the cognitive change were not significant. The variance for the random intercept and slope (change) were estimated as 0.25 and 0.29, respectively, and the correlation between the intercept and slope was nearly 1.00. The residual variance was 0.55.

Given the prediction of differential change across measures, we fit the full version of Model (1) that allows for subtest specific regression coefficients for the subtests and for the EM/EF factors to identify what subtests drove the global effects that were found from the analysis reported above. For the follow-up analyses, the variance for the random intercept and slope (change) were estimated as 2.67 and 2.85, respectively from the multivariate analysis (of the seven subtests) and 0.26 (intercept) and 0.31 (slope) for the bivariate analysis of the EM and EF factors. The correlation between the random intercept and slope was close to 1.00 from both analyses, indicating that the two random effect terms (intercept and change) were not differentiable.

Table 6. Parameter estimates of the multivariate linear mixed effects model

	Immediate word list recall	Delayed word list recall	Number series	Category fluency	Backward digit span	30-SACT backward counting	SGST latency	Episodic memory	Executive functioning
MIDUS 2									
Intercept	6.154***	3.747***	2.389***	19.019***	4.928***	38.753***	1.062***	−0.261***	0.085***
(*SE*)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.02)	(0.02)
95% CI	[5.95, 6.36]	[3.54, 3.95]	[2.19, 2.59]	[18.82, 19.22]	[4.73, 5.13]	[38.55, 38.96]	[0.86, 1.27]	[−0.30, −0.22]	[0.05, 0.12]
δ	1.276	0.777	0.495	3.945	1.022	8.038	0.220	−0.25	0.08
Age	−0.053***	−0.063***	−0.026**	−0.134***	−0.017*	−0.366***	−0.007	−0.015***	−0.018***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.0005)	(0.01)	(0.01)	(0.002)	(0.002)
	[−0.06, −0.04]	[−0.08, −0.05]	[−0.04, −0.01]	[−0.15, −0.12]	[−0.03, −0.01]	[−0.38, −0.35]	[−0.02, −0.00]	[−0.02, −0.01]	[−0.02. −0.01]
	−0.011	−0.013	−0.005	−0.028	−0.004	−0.076	−0.002	−0.014	−0.018
Sex	1.056***	1.187***	−0.233	−0.431**	0.139	−2.753***	−0.081	0.422***	−0.153**
	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.06)	(0.06)
	[0.78, 1.33]	[0.90, 1.47]	[−0.51, 0.04]	[−0.71, −0.16]	[−0.14, 0.41]	[−3.03, −2.48]	[−0.36, 0.20]	[0.31, 0.53]	[−0.26, −0.05]
	0.218	0.245	−0.048	−0.089	0.029	−0.569	−0.017	0.409	−0.148
Education	0.172***	0.169***	0.216***	0.708***	0.104***	0.964***	0.013	0.082***	0.144***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)
	[0.12, 0.22]	[0.12, 0.22]	[0.16, 0.27]	[0.66, 0.76]	[0.05, 0.16]	[0.91, 1.02]	[−0.04, 0.07]	[0.06, 0.10]	[0.12, 0.17]
	0.036	0.035	0.045	0.147	0.022	0.199	0.003	0.079	0.140
MIDUS 3- MIDUS 2									
Age	−0.022*	−0.020*	−0.023**	−0.054***	−0.013	−0.066***	−0.007	−0.010***	−0.012***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.002)	(0.002)
	[−0.04, 0.00]	[−0.04, 0.00]	[−0.04, −0.01]	[−0.07, −0.04]	[−0.03, 0.00]	[−0.08, −0.05]	[−0.03, 0.01]	[−0.007, −0.01]	[−0.02, −0.01]
	−0.005	−0.004	−0.005	−0.011	−0.003	−0.014	−0.001	−0.010	−0.012
Sex	0.119	0.240	−0.055	0.409*	−0.049	0.212	0.025	0.059	−0.003
	(0.22)	(0.22)	(0.22)	(0.21)	(0.22)	(0.22)	(0.22)	(0.04)	(0.04)
	[−0.31, 0.54]	[−0.19, 0.68]	[−0.48, 0.37]	[−0.00, 0.82]	[−0.47, 0.37]	[−0.21, 0.64]	[−0.41, 0.46]	[−0.01, 0.13]	[−0.08, 0.07]
	0.025	0.050	−0.011	0.085	−0.01	0.044	0.005	0.058	−0.003
Education	−0.008	−0.021	−0.007	−0.107**	0.002	−0.024	−0.0004	−0.008	−0.011
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.007)	(0.007)
	[−0.09, 0.07]	[−0.11, 0.06]	[−0.09, 0.07]	[−0.19, −0.03]	[−0.08, 0.08]	[−0.11, 0.06]	[−0.09, 0.08]	[−0.02, 0.01]	[−0.03, 0.00]
	−0.002	−0.005	−0.002	−0.022	0.00	−0.005	−0.001	−0.008	−0.011

Note. Standard errors are provided in the parenthesis. δ is the effect size.
A single asterisk indicates significance at $p < .05$.
A double asterisk indicates significance at $p < .01$.
A triple asterisk indicates significance at $p < .001$.

The level-1 residual variance was estimated to be 17.72 and 0.49 from the multivariate and bivariate analyses, respectively. The parameter estimates of the regression coefficients are presented in Table 6. The main effect of age (on the intercept) was negative and significant at $p < .001$ for four subtests, with the exception of backward digit span ($p < .05$), number series ($p < .01$), and SGST (not significant), as well as for both EM and EF factors, all with very small effects size δ. The effect of sex was significant at the 0.001 level for three subtests, except for category fluency and the EF factor ($p < .05$), and SGST, backward digit span, and number series were not significant. Women had higher mean scores for immediate and delayed word list recall, and the EM factor, all indicating very small effect sizes in terms of δ. Men scored better on the 30-SACT backward counting, category fluency, and the EF factor. The effect of education years was positive and significant at the 0.001 level for the EM and EF factors and six subtests, again in contrast to the overall model, except for the SGST (not significant).

For change, the effect of age was negative and significant at $p < .001$ for 30-SACT, category fluency, EM, and EF, at $p < .01$ for number series, and at $p < .05$ level for word list immediate and delayed. Although in the overall model, the effects of sex and education years on change were not significant in the multivariate model, for descriptive purposes we examined these effects for individual tests, and found significant effects only for category fluency, at the .05 and .01 levels, respectively; women showed less decline and those with higher education showed greater decline.

We plotted the mean score change (MIDUS 3 minus MIDUS 2) for each subtest as a function of age (at the time of MIDUS 2). A bivariate smoother Loess curve was used to fit a

Table 7. Mean scores and standard errors for cognitive subtests and factors for longitudinal sample by age decade for MIDUS 2 and MIDUS 3 assessments

		Age decade at MIDUS 2				
		30s	40s	50s	60s	70s and up
Subtests						
Immediate word list recall	MIDUS 2	7.70 (.16)	7.35 (.08)	7.24 (.08)	6.68 (.09)	5.76 (.13)
	MIDUS 3	7.67 (.14)	7.51 (.09)	6.94 (.08)	6.21 (.10)	4.72 (.11)
	N	202	637	773	600	290
Delayed word list recall	MIDUS 2	5.75 (.19)	5.28 (.09)	4.71 (.09)	4.28 (.10)	3.42 (.14)
	MIDUS 3	5.46 (.18)	5.30 (.10)	4.50 (.09)	3.79 (.11)	2.37 (.14)
	N	190	606	719	552	243
Number series	MIDUS 2	2.97 (.10)	2.85 (.06)	2.62 (.05)	2.19 (.06)	1.79 (.08)
	MIDUS 3	3.11 (.10)	2.89 (.06)	2.44 (.05)	1.82 (.06)	1.30 (.08)
	N	203	635	770	578	262
Category fluency	MIDUS 2	22.52 (.48)	21.06 (.23)	20.00 (.21)	18.20 (.24)	17.28 (.31)
	MIDUS 3	22.43 (.45)	20.85 (.23)	19.25 (.20)	16.97 (.23)	14.74 (.30)
	N	203	636	778	601	292
Backward digit span	MIDUS 2	5.45 (.10)	5.25 (.06)	5.08 (.05)	5.00 (.06)	4.71 (.09)
	MIDUS 3	5.32 (.09)	5.33 (.06)	5.04 (.05)	4.76 (.06)	4.23 (.08)
	N	204	637	777	601	293
30-SACT backward counting	MIDUS 2	45.82 (.90)	42.58 (.42)	39.67 (.38)	34.45 (.38)	31.08 (.50)
	MIDUS 3	44.33 (.87)	41.26 (.42)	37.17 (.38)	31.43 (.39)	27.76 (.48)
	N	203	631	775	594	286
SGST latency	MIDUS 2	0.98 (.01)	1.01 (.01)	1.04 (.01)	1.13 (.01)	1.18 (.02)
	MIDUS 3	1.16 (.03)	1.17 (.01)	1.25 (.01)	1.37 (.02)	1.43 (.03)
	N	197	604	737	559	253
Episodic memory	MIDUS 2	0.49 (.07)	0.32 (.03)	0.19 (.03)	−0.04 (.04)	−0.42 (.05)
	MIDUS 3	0.43 (.06)	0.36 (.04)	0.07 (.03)	−0.26 (.04)	−0.90 (.05)
	N	202	637	773	601	292
Executive functioning	MIDUS 2	0.75 (.07)	0.50 (.03)	0.25 (.03)	−0.16 (.04)	−0.49 (.05)
	MIDUS 3	0.47 (.07)	0.26 (.04)	−0.15 (.03)	−0.70 (.04)	−1.14 (.05)
	N	204	637	779	602	293

Note. Standard errors are presented in parentheses.

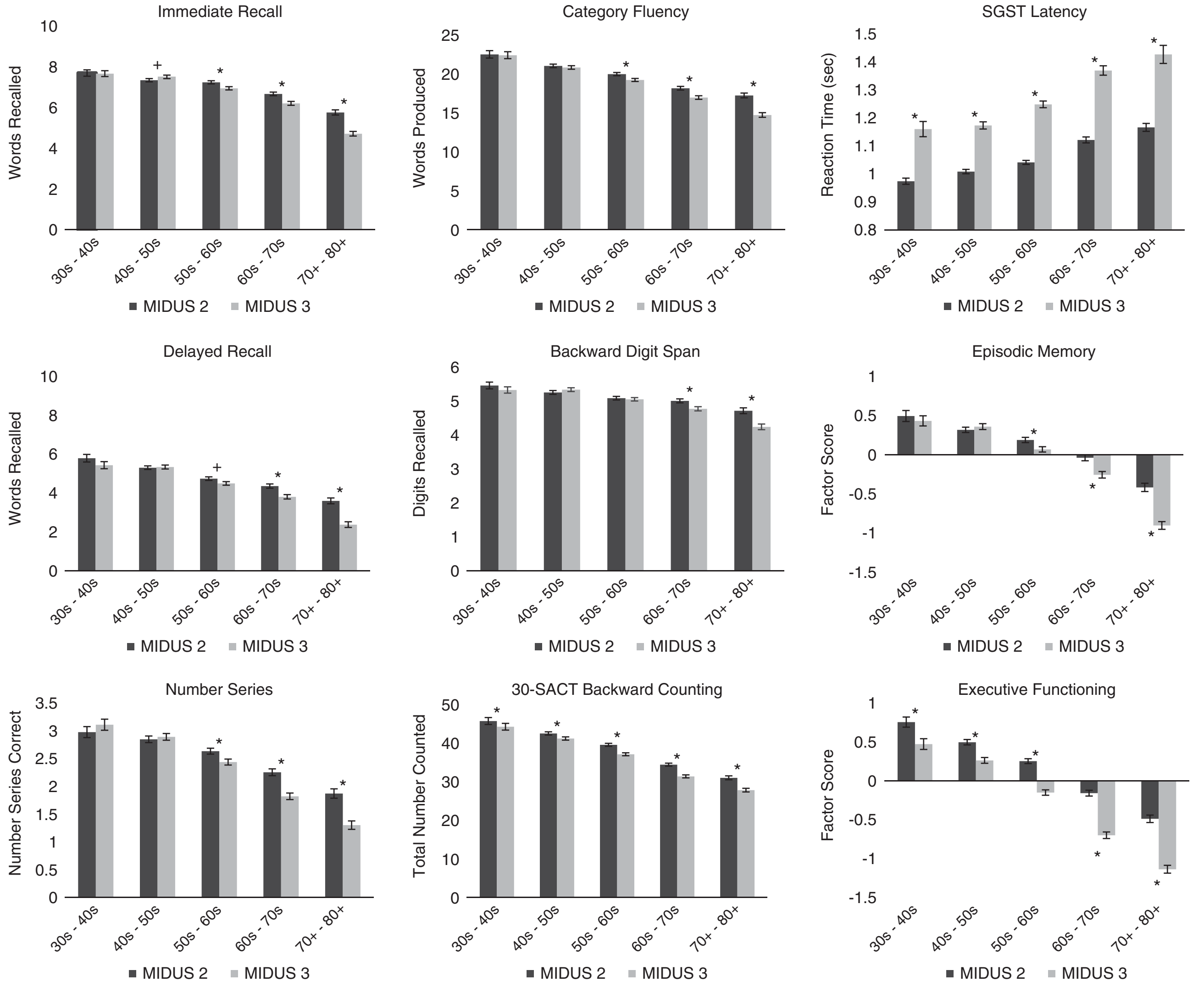

Fig. 1. Mean subtest and factor scores at MIDUS 2 and MIDUS 3 for the longitudinal sample by age decade at MIDUS 2 (dark bars) and MIDUS 3 (light bars). Note: An asterisk indicates significant change at $p < .001$, and a dagger indicates significant change at $p < .05$ within age groups based on pairwise comparisons from the doubly multivariate analysis with repeated measures (see Supplementary Table S2).

smooth curve of the scatter plots between the change scores for the two continuous variables and age. The results are presented in Supplementary Figure S1. The plots show that there is decline for all seven subtests and two factors and the extent of decline differs somewhat across the measures (see Table 6). In Table 7 and Figure 1, we present the raw mean subtest scores at MIDUS 2 and MIDUS 3 for the longitudinal sample by age decade. We conducted a doubly multivariate repeated measures analysis to examine the effects of subtest, age (by decade), sex, education (Less than BA, BA, or Higher), and time (see Supplementary Table S2). The two repeated measures were subtest and time.

The seven MIDUS 3 subtests were standardized using means and standard deviations from MIDUS 2. We found significant main effects of time [$F(1,2143) = 428.52$; $p < .001$, $\eta^2_p = .17$], age [$F(4,2143) = 119.43$; $p < .001$; $\eta^2_p = .18$], and education [$F(1,2143) = 215.19$; $p < .001$; $\eta^2_p = .09$]. We also found a significant subtest X age X time interaction, $F(24,7459.8) = 1.84$, $p = .008$, $\eta^2_p = .005$ (see Supplementary Table S2). Pairwise comparisons with Bonferroni corrections revealed that the pattern and extent of changes varies by subtest and by age (see Figure 1). For example, for the 30-SACT backward counting the decline starts as early as the 30s [$F(1,2143) = 11.22$; $p = .001$; $\eta^2_p = .005$]. For the SGST latency, the reaction time increased steadily with age starting from the 30s [$F(1,2143) = 37.22$; $p < .001$; $\eta^2_p = .02$]. The immediate word list recall demonstrated significant decline beginning in the 40s [$F(1,2143) = 4.24$; $p = .04$; $\eta^2_p = .002$]. For number series [$F(1,2143) = 14.59$; $p < .001$; $\eta^2_p = .007$], category fluency [$F(1,2143) = 13.87$; $p < .001$; $\eta^2_p = .006$], and word list delayed [$F(1,2143) = 5.70$; $p = .02$; $\eta^2_p = .003$], the decline started somewhat later in the 50s. For backward digit span, the declines became significant from the 60s to the 70s [$F(1,2143) = 8.87$; $p = .003$; $\eta^2_p = .004$].

Finally, we conducted a doubly multivariate repeated measures analysis to examine the effects of factor, age, sex, education, and time (see Supplementary Table S2). The two repeated measures were factor and time. The results revealed significant main effects of age [$F(4,2479) = 168.08$; $p < .001$;

$\eta_p^2 = .21$], education [$F(1,2479) = 219.17$; $p < .001$; $\eta_p^2 = .08$], sex [$F(1,2479) = 33.39$; $p < .001$; $\eta_p^2 = .01$], and time [$F(1,2479) = 407.40$; $p < .001$; $\eta_p^2 = .14$]. We also found several significant interactions. For the interaction of factors with age [$F(4,2479) = 10.61$; $p < .001$; $\eta_p^2 = .02$], the pattern of age differences varied by factor. For the EM factor, pairwise comparisons demonstrated that there was no difference between the 30s and the 40s, but each subsequent decade scores significant lower than the last. For the EF factor, there was significicantly lower scores for all older decades. For the factor by sex interaction [$F(1,2479) = 252.46$; $p < .001$; $\eta_p^2 = .09$], females had a higher EM factor score than men, but men had a higher EF factor score compared to women. For the factor by education interaction [$F(1,2479) = 64.45$; $p < .001$; $\eta_p^2 = .03$], more highly educated participants had higher scores on both factors.

However, the difference between the two education groups was larger for the EF factor than for EM factor. For the factor by time interaction [$F(1,2479) = 103.47$; $p < .001$; $\eta_p^2 = .04$], both factor scores declined over time, but the decline was more pronounced for the EF score than the EM score. Finally, for the time by age interaction [$F(4,2479) = 33.25$; $p < .001$; $\eta_p^2 = .05$], decline was greater in older adults. The three-way interaction between factor, time, and age was not significant.

Retest Effects

In longitudinal analyses, the effects of retesting, a threat to internal validity, must be considered. To test for retest effects we examined differences between the MIDUS sample who had been tested twice and a sample recruited in the same manner, who had been tested only once (Refresher sample). The MIDUS Refresher sample was recruited between 2011 and 2014 to replenish the original MIDUS cohort. An additional 3,577 adults who ranged in age from 23 to 76 were recruited into the Refresher sample. As with the previous waves of MIDUS, the BTACT was administered in a separate telephone interview with a completion rate of 71.3% ($N = 2550$). The Refresher cognitive sample had a mean age of 52.60 ($SD = 14.17$) and a mean education of 14.99 years ($SD = 2.54$). The sample was made up of 52.2% women and had a mean self-rated health of 3.55 ($SD = 1.07$).

To assess retest effects, we specified a linear regression model for a pooled dataset (MIDUS 3 and MIDUS Refresher sample). We compared the mean score values of each subtest between the refresher sample and MIDUS 3 (after controlling for education years and age differences between the samples). If there were retest effects, the MIDUS 3 sample would show higher mean scores than the refresher sample. The analysis results, however, suggest that the refresher sample showed significantly higher mean values on five subtests than the MIDUS 3 sample (all except SGST and backward digit span) at the .05 level. Specifically, the difference (MIDUS Refresher - MIDUS 3) was 0.31 ($SE = 0.06$; 95% CI [0.18, 0.43]; $\eta_p^2 = 0.0048$) for immediate word list recall, 0.26 ($SE = 0.07$; 95% CI [0.11, 0.40]; $\eta_p^2 = 0.0026$) for delayed word list recall, 0.08 ($SE = 0.04$; 95% CI [0.003, 0.16]; $\eta_p^2 = 0.0008$) for number series, 0.93 ($SE = 0.29$; 95% CI [1.36, 2.50]; $\eta_p^2 = 0.0087$) for 30-SACT backward counting, and 1.04 ($SE = 0.16$; 95% CI [0.73, 1.36], $\eta_p^2 = 0.0083$) for category fluency. In terms of the effect size measure η_p^2, all reported differences indicated neglible effects.

DISCUSSION

The present set of results adds to our knowledge about the nature and extent of cognitive changes during the middle and later years of adulthood using a large national U.S. sample and wide age range, with adults from the mid-30s into the early 90s. Results indicated that some cognitive changes begin as early as the 30s and 40s, whereas other aspects begin to decline some 10 to 20 years later, in the 50s and 60s (see Figure 1 and Supplementary Figure S1). The measures of speed and reaction time showed the earliest changes, beginning in adults who aged from the 30s to the 40s over the 9 years. In contrast, backward digit span did not show declines until the 60s and 70s. Immediate recall showed declines in the 40s, and reasoning, delayed word recall, and category fluency showed declines beginning in the 50s.

For all of the cognitive tests, the extent of decline became steeper with age. There was evidence for a factorial invariance, and both factors declined significantly over the 9 years, and the decline (cognitive change) was significantly larger at later ages for both episodic memory and executive functioning factors. Although the amount of change was significant, the effects sizes were very small to trivial, suggesting there are substantial individual differences within age groups in the direction and extent of change. The very small effect sizes highlight the need to be cautious in interpreting the practical implications of the declines.

Differences were also found by education and sex. Consistent with past work, those with greater educational attainment had higher levels of cognitive performance across measures. There has been inconsistent evidence regarding the degree of change in relation to education. In some studies, it has been suggested that there are only differences in level of performance, and the slopes do not differ by education in normal cognitive aging (Stern, 2002; 2009; Tucker & Stern, 2011; Zahodne et al., 2011). A recent review of 10 studies found little evidence that education moderates the rate of age-related cognitive decline (Lenehan, Summers, Saunders, Summers, & Vickers, 2015), although some have found those with greater cognitive reserve (e.g., higher education) show steeper decline in later life for verbal memory (Alley, Suthers, & Crimmins, 2007) and faster progression of decrements among those with dementia including Alzheimer's disease (Scarmeas, Albert, Manly, & Stern, 2006; Stern, 2012).

In the current study, we found education was significantly related to performance on all subtests and factors except for SGST reaction time, although only related to change for one subtest. Those with higher levels of education showed steeper decline in category verbal fluency, but these results may be spurious given that the multivariate effect was not significant.

Sex differences were consistent with previous research (Jorm, Antsey, Christensen, & Rodgers, 2004; Caselli et al., 2015). Women did better on episodic memory tasks (immediate and delayed word list recall), while men did better on executive functioning, and the category fluency and speed tasks. The sex differences were generally consistent over time and across age decades, except that women showed less decline on category fluency than men did. Given that this was an exploratory analysis and the multivariate effect was not significant, the results should be interpreted conservatively.

Recent work has demonstrated that sex differences in episodic memory are attenuated for women after menopause (Rentz et al., 2017). Whereas pre- and peri-menopausal women outperformed men on all memory measures, post-menopausal women no longer showed an advantage relative to men on memory (Rentz et al., 2017). In the current study, women maintained higher performance than men on episodic memory across the age decades. However, in future work it will be important to consider whether menopausal status plays a role in memory for women, as suggested by the Study of Women Across the Nation (Karlamangla, Lachman, Han, Huang, & Greendale, 2017).

Our comparison of the longitudinal and the refresher samples provided a way to examine retest effects (Gross et al., 2015). The results suggest there were no significant retest effects, consistent with other studies with intervals greater than 7 years (Salthouse, Schroeder, & Ferrer, 2004). Indeed, our results are more consistent with cohort differences than with retest effects. Ideally in the future, however, we would test for retest effects with two samples from the same cohorts who were tested at the same point in time.

Importance of Cognitive Functioning

Effective cognitive function through adulthood is a key element not only in quality of life, but also in the ability to maintain independence (Royall, Palmer, Chiodo, & Polk, 2005). Cognitive functioning has been linked to health in later life, yet this relationship has rarely been explored for young adulthood and middle age. In older adults, cognitive functioning has been associated with morbidity and mortality (Bruce, Hoff, Jacobs, & Leaf, 1995; Swan et al., 1995), lung function (Cook et al., 1995), cardiovascular disease (Elias, Elias, Robbins, Wolf, & D'Agostino, 2000; Karlamangla et al., 2005), sensory/motor functioning (Lindenberger & Baltes, 1994; Wingfield, Tun, & McCoy, 2005), diabetes (Stewart & Liolitsa, 1999; Wu et al., 2008; Yeung, Fischer, & Dixon, 2009), stress and allostatic load (Seeman, McEwen, Singer, Albert, & Rowe, 1997), and functional ability (Greiner, Snowdon, & Schmitt, 1996; Moritz, Kasl, & Berkman, 1995).

It is important to examine cognitive functioning in midlife during the early stages of disease processes. This can provide opportunities for early detection of cognitive impairments with possibilities for preventative interventions. Results using the BTACT are consistent with findings using longer batteries with multiple indicators and administered in person. The results may be useful for those interested in using a brief telephone measure to compare clinical samples with this large normative sample. For example the BTACT has been adopted in several studies of traumatic brain injury and chronic traumatic encephalopathy (e.g., Alosco et al., 2018; Dams-O'Connor et al., 2018).

Limitations

The use of cell phones for the cognitive interview became more prevalent by MIDUS 3. This poses some issues for the SGST reaction time task given that cell phone transmission of responses is generally slower than on landline phones. The transmission rate varies as a function of the cell phone carrier, distance from cell towers, and time of day due to differential usage. The metronome task we developed to address and correct for this delay has some limitations. For example, although the counting responses are expected to reflect the lag in cell phone transmission, to some extent it may also reflect individual differences in the ability to keep the beat rhythm. Nevertheless, when we examined the effects of telephone type, the results for cell phones with the corrected scores did not differ from the landline phone results.

The MIDUS sample, although originally drawn as a random, representative sample of adults in the United States, is now positively selected due to attrition. Moreover, the sample is not representative of the United States in terms of minority representation. Although we have characterized the longitudinal sample in terms of how they differ from the dropouts in term of demographic and cognitive variables, it is the case that the findings may have underestimated the nature of aging-related cognitive changes. Given that those who remain in the longitudinal sample after 20 years are better educated, healthier, and have better cognitive functioning, this limits the generalizability of the findings. Although our analyses did not find evidence for retest effects, given that the longitudinal sample was tested twice, there is the possibility that retest effects are operating to inflate scores. The factor structure for the BTACT was invariant over time, and the best fit was found for weak invariance involving only the number of factors and factor loadings. The more restricted models, however, also were acceptable, although they did not fit the data as well.

It should also be noted that given the MIDUS study sampling strategy, there were more participants in the 40 to 60 range than in the 30s or over 70. Such variation in sample size could affect the homegeniety of variance. However, as all age groups were sufficiently powered, and the statistical analyses tend to be robust to the influence of unequal sample sizes, this is unlikely to have affected the overall pattern of results.

Another limitation of the study is that, in the absence of brain imaging data, it is unclear to what extent the behavioral declines are reflective of brain pathology, cognitive impairment, or diseases associated with normal aging. As the sample now includes a substantial number who are over the age of 65, the MIDUS investigators are exploring ways to address this issue in the future by harmonizing with other studies with similar test batteries and dementia assessments (e.g., HRS) and by including dementia screeners to provide more information about cognitive status.

Future Directions

Given the rich set of biopsychosocial variables available in the MIDUS data set, we can articulate and test a large set of conditions and lifestyles that may put adults at risk for cognitive decline (Agrigoroaei & Lachman, 2011). Moreover, we will be able to examine patterns of resilience and protective factors in terms of cognitive and physical health. The present analysis of differential change trajectories over a 9-year period sets the stage for future work that will examine individual differences, that is, why some people fare better than others in their cognitive functioning throughout adulthood.

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Supplementary Materials

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