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Occupational cognitive complexity and episodic memory in old age

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ABSTRACT

The aim of this study was to investigate occupational cognitive complexity of main lifetime occupation in relation to level and 15-year change in episodic memory recall in a sample of older adults ($\geq$ 65 years, $n = 780$). We used latent growth curve modelling with occupational cognitive complexity (O*NET indicators) as independent variable. Subgroup analyses in a sample of middle-aged (mean: 49.9 years) men ($n = 260$) were additionally performed to investigate if a general cognitive ability (g) factor at age 18 was predictive of future occupational cognitive complexity and cognitive performance in midlife. For the older sample, a higher level of occupational cognitive complexity was related to a higher level of episodic recall ($\beta = 0.15$, $p < .001$), but the association with rate of change ($\beta = 0.03$, $p = .64$) was not statistically significant. In the middle-aged sample, g at age 18 was both directly ($\beta = 0.19$, $p = .01$) and indirectly (via years of education after age 18, $ab = 0.19$) predictive of midlife levels of occupational cognitive complexity. Cognitive ability at age 18 was also a direct predictor of midlife episodic recall ($\beta = 0.60$, $p \leq 0.001$). Critically, entry of the early adult g factor attenuated the association between occupational complexity and cognitive level (from $\beta = 0.21$, $p = .01$ to $\beta = 0.12$, $p = .14$). Overall, our results support a pattern of preserved differentiation from early to late adulthood for individuals with different histories of occupational complexity.

1. Introduction

The relative proportion of older people is increasing worldwide (United Nations, 2019). Aging is typically associated with a decline in cognitive functions and an increased risk of dementia disorders (e.g., Bäckman, Jones, Berger, Laukka, & Small, 2005; Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). Therefore it is of paramount importance to identify factors with the potential to preserve cognitive functions in older age. In this regard, several factors have been suggested to be beneficial, for example, a higher educational level (e.g., Ritchie & Tucker-Drob, 2018), engagement in physical and mentally stimulating activities (for reviews, see e.g., Stern & Munn, 2010; Fallahpour, Borell, Luborsky, & Nygård, 2015), media multi-tasking (Elbe, Sörman, Mellqvist, Brändström, & Ljungberg, 2019) and bilingualism (Ljungberg, Elbe, & Sörman, 2019; Bialystok et al., 2007; Ossher et al., 2013). The basic idea is that forms of environmental enrichment can promote cognitive functions and minimize decline, even in the long-term (Stern, 2002). An aspect which has received particular interest in recent years, are occupations with high mental requirements (Fisher et al., 2014; Lane, Windsor, Andel, & Luszcz, 2017; Pool et al., 2016; Vemuri et al., 2014). The potential effects of occupation on cognitive functions may be of particular interest because most individuals spend a large portion of their lifetime at work.

The current study focused on occupational complexity as a factor to account for cognitive level and rate of decline (see e.g., Bosma, Van Boxtel, Ponds, Houx, & Jolles, 2003; Correa Ribeiro, Lopes, & Lourenço, 2013; Fisher et al., 2014; Gajewski et al., 2010; Lane et al., 2017; Pool et al., 2016; Schooler, Mulatu, & Oates, 1999; Singh-Manoux et al., 2011; Vemuri et al., 2014). With regard to the current evidence, a positive association between complexity at work and *level* of cognitive ability is typically observed, and this association appears to generalize across various measures of various cognitive functions, including global measures of cognition (e.g., Correa Ribeiro et al., 2013), executive functions (e.g., Sörman, Hansson, Pritschke, & Ljungberg, 2019),

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processing speed (e.g., Ansiau, Marquié, Soubelet, & Ramos, 2005; Smart, Gow, & Deary, 2014), verbal fluency (Van der Elst, Van Boxtel, & Jolles, 2012), cognitive flexibility (e.g., Gajewski et al., 2010), episodic memory (e.g., Fisher et al., 2014) as well as attention and orientation (e.g., Scherr et al., 1988).

With regard to longitudinal changes in cognition, some studies suggest that a history of working in mentally demanding occupations is associated with less cognitive decline (e.g., Bosma et al., 2003; Gajewski et al., 2010). Andel, Finkel, and Pedersen (2016), for example, found that highly complex work with people reduced cognitive decline after retirement in terms of verbal ability, memory, and speed of processing over a 14-year period. By contrast, some studies demonstrated a pattern of *greater* decline among individuals with a history of working in high-complexity occupational positions (e.g., Singh-Manoux et al., 2011). Based on a 13-year follow-up, Lane et al. (2017) found that complex work with data was associated with better performance in cognitive speed, memory, and mental status, but not with rate of change. The authors did not have access to early-life cognitive data, and thus concluded that early-life influences on later cognitive ability remained to be established. Finkel, Andel, Gatz, and Pedersen (2009) suggested that highly complex work with people in one's main lifetime occupation influenced cognitive aging differently dependent on the age period and cognitive ability investigated. For instance, their 20-year follow-up showed that highly complex work with people was related both to higher verbal function *before* retirement and faster decline in spatial ability *after* retirement.

Different hypotheses have been put forward to explain the mechanisms underlying the associations between stimulating factors and their effects on cognitive functions. Here we review three of the most influential hypotheses. The first is the *differential preservation hypothesis* (Tucker-Drob, Johnson, & Jones, 2009). This hypothesis suggests that individuals who engage in mental activities show superior initial levels of cognitive performance, but also that the exercise of cognitive skills slows the rate of cognitive decline in old age. A theoretical notion related to differential preservation, often proposed to explain how cognitive stimulation influences cognitive functions later in life, is the *cognitive reserve hypothesis*. The idea here is that enduring cognitive stimulation builds up cognitive resources (Schooler & Mulatu, 2001) that may slow the rate of cognitive decline in healthy older adults and postpone the onset of behavioural changes in the presence of dementia pathology (Scarmeas & Stern, 2003). Sufficient cognitive stimulation could produce both an improvement of the ability to efficiently use cognitive components and brain networks (Stern, 2002) and an increase in the ability to recruit additional brain networks to compensate for negative brain changes (Hultsch, Hertzog, Small, & Dixon, 1999; Scarmeas & Stern, 2003; Tucker & Stern, 2011).

An alternative hypothesis is the *preserved differentiation hypothesis* (see e.g., Bielak, 2010; Bielak, Anstey, Christensen, & Windsor, 2012; Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990), which posits that mental engagement may be correlated with cognitive functioning without influencing the rate of cognitive age change. This would be consistent with reverse causation (Bielak, 2010, Bielak et al., 2012; Gow, Avlund, & Mortensen, 2014; Gow, Mortensen and Avlund, 2012, Salthouse, 2006), meaning that individuals with a high level of cognitive ability are more likely to have a mentally demanding lifestyle. This pattern is also present in old age, with similar stability in differences between individuals, and with similar rate of cognitive change (preserved differentiation). Thus, the hypothesis of preserved differentiation posits a more static view of cognitive aging, and suggests that mental activity largely mirrors prior or current level of cognitive status.

In recent decades, several studies have demonstrated a pattern of preserved differentiation (see e.g., Gow et al., 2014), or at least highlighted that prior cognitive ability is both a crucial factor for cognitive function later in life (Deary, Whalley, Lemmon, Crawford, & Starr, 2000) and one determinant of lifestyle patterns such as engagement in mentally stimulating leisure activities (e.g., reading, playing chess; see Gow et al., 2012). Tucker-Drob et al. (2009), for instance, found that factors often considered as predictors of cognitive reserve (vocabulary and years of education) were related to level of performance in tasks measuring reasoning and cognitive speed in old age (≥65 years). However, the cognitive reserve indexes considered were unrelated to rate of change in their 5-year follow-up.

Smart et al. (2014) investigated relationships between early life cognitive ability, occupational complexity (with data, people, or things), and cognitive aging using work classifications according to the Dictionary of Occupational Titles (DOT; U.S. Department of Labor, 1977). The data were drawn from the Lothian Birth Cohort (Scotland) where data on childhood intelligence (IQ at age 11) are available. The results showed that occupational complexity in working with people or data in midlife was related to better cognitive ability in old age ($M = 70$ years) in separate linear regression models, whereas complexity in working with things was not. Complexity in working with people was related to IQ at age 70 (Moray House Test) and a *g* factor (6 of Wechsler Adult Intelligence Scale subtests). Working with data was related to the *g* factor and processing speed. These findings were significant beyond the influence of age, sex, years of education, and early IQ. Thus, these results support the notion that midlife occupational complexity is related to later life cognitive ability. However, results from this study also showed that relationships between occupational complexity factors and cognitive abilities were strongly reduced (up to 70%) when childhood IQ was adjusted for, demonstrating that early intelligence can predict much of the future level of occupational complexity. No longitudinal data was available to evaluate associations of work complexity and cognitive change, though, and the authors concluded that there was a need for more studies that could control for early-life cognitive ability.

In the aforementioned study, years of education was entered as a covariate. Education is a factor that can be viewed as a proxy of intelligence, but also as an environmental variable that reflects, for instance, social status and learned knowledge (Deary & Johnson, 2010). Even if it is well known that early-life cognitive ability has an influence on future life course factors such as education, occupation, health behaviors, and cognitive health via selection factors (Hofer & Clouston, 2014) some argue that education benefits health and cognition later in life through increased cognitive stimulation (Stern, 2002) and higher socioeconomic status (Vance, Ross, Ball, Wadley, & Rizzo, 2007), but also because gained knowledge may increase the likelihood of making lifestyle choices that are beneficial for health and cognitive functioning (Bukov, Maas, & Lampert, 2002). Clouston et al. (2012), for example, found that having a university education was associated with a higher level of fluid cognition in adulthood (early 50s) even when cognitive performance in adolescence (15–16 years) was adjusted for. Hence, viewed from these results education might have some influence on late life cognition partly independent from early levels of intelligence. Other studies also note that health associations with intelligence may be attributable to differences in education, and that it may be a factor that can act as mediator of intelligence–health outcomes (Calvin et al., 2011; Deary, Hill, & Gale, 2021). It should be noted though that other findings suggest that additional education after age 20 or so has a limited influence, if any, on late midlife cognitive functioning (see e.g., Kremen et al., 2019; Rönnlund, Sundström and Pudas, 2017).

Until today only a few longitudinal studies have had access to early-life cognitive data. As stressed by Deary et al. (2000), prior cognitive ability is a crucial factor to understand cognitive aging. Potter, Helms, and Plassman (2008) were probably the first researchers to include measures of both early-age cognitive ability (armed services testing) and cognitive demands at work along with late-life global cognitive status. The sample in their twin study included World War 2 veterans, and the results revealed an interaction effect suggesting that individuals with lower cognitive ability earlier in life profit more from 'general intellectual demands' compared to individuals with high early-age cognitive ability. Because the study was a retrospective cross-sectional correlation study, it did not investigate the rate of cognitive change in old age.

For the assessment of occupational complexity, many studies used the abovementioned DOT classifications (U.S. Department of Labor, 1977), in which occupations are categorized into complexity of working with data, people, and things. An alternative way to measure occupational complexity is to use the Occupational Information Network (O*NET) database, which includes a broad set of variables for about 1000 occupations (Handel, 2016; Peterson et al., 2001; Peterson, Mumford, Borman, Jeanneret, & Fleishman, 1999). The O*NET database is more advanced than the DOT because it has more fine-grained information about occupational characteristics (Handel, 2016; Peterson et al., 1999). All of the occupations in O*NET have been rated by analysts, incumbents, and occupational experts in terms of the required level and importance of several dimensions (Handel, 2016; Peterson et al., 2001). So far, only a few studies have related the O*NET dimensions to cognitive functions. Then et al. (2015) found that individuals aged ≥75 years from occupations that stimulated verbal intelligence performed better on the Mini-Mental State Examination (MMSE) at baseline, and also showed a lower rate of cognitive decline over a follow-up period of 8 years, compared to individuals from occupations with low demands on verbal intelligence. Fisher et al. (2014) used a composite score calculated from ten variables assumed to reflect 'mental job demands' to similarly show that work demands could predict better performance in both episodic memory recall and 'mental status' (composite of several measures), and also predict slower rate of cognitive decline after retirement. Similar results were obtained in older participants (> 65 years) when measuring global cognition (Pool et al. (2016).

1.1. Purpose of the present study

Given that prior studies yielded some mixed evidence regarding the relations between work complexity and cognitive ability level and change in adulthood/old age, the purpose of the present study was evaluate these associations further. Critically, we considered early-life cognitive ability which is required to control for the possibility that work-cognition associations at an advanced age reflects variations in early adult cognitive level.

The data were drawn from a Swedish longitudinal study, the Betula prospective cohort study (Nilsson et al., 1997; Nyberg et al., 2020) which allowed us to: (i) to investigate if history of occupational cognitive complexity was related to cognitive level and long-term (baseline, 5 years, 10 years, and 15 years) changes past age 65; (ii) to examine the relationships between early life cognitive ability, occupational cognitive complexity, and cognitive performance in a sub-sample of middle-aged men (45–55 years) for which cognitive test scores at age 18 were retrieved from the Swedish military archives; (iii) to investigate if years of education after the age of 18 mediates the relationship between early life cognitive ability (18 years) and occupational cognitive complexity and episodic memory recall; and (iiii) to compare patterns of relationships found in the analysis of the middle-aged sample to those found in the analyses of the older-aged sample, and to interpret if adult *g* may act as a potential confound between occupational complexity and episodic memory over the whole life span.

To assess work complexity we used O'NET, which, despite its large number of benefits, has rarely been used to evaluate similar associations (but see Fisher et al., 2014). The cognitive outcome factor considered in the present study was episodic memory recall (Nyberg et al., 2003). Episodic memory involves memory for personal events (Tulving, 1983), and allows for what has been referred to as mental time travel that is critical to maintain ones identity but is also critical to prospection (future thinking and planning) and other cognitive functions such as decision making. Another fact that motivates a focus on episodic memory, and recall (rather than recognition, which has been regarded as a separate facet of episodic memory, Nyberg et al., 2003) is that episodic recall is very age-sensitive (e.g. Park et al., 2002), with a marked mean-level decline after age 65 even in longitudinal analyses (Rönnlund et al., 2005). Moreover, episodic memory is often a hallmark sign of dementia, especially Alzheimer's disease (Bäckman et al., 2005). Finally, a specific focus on episodic memory was motivated by the fact that the Betula study aimed to cover this aspect of cognition in particular and had included multiple marker, in turn allowing for a latent-level analytic approach instead of, as in many prior studies, analyses of single markers of cognitive abilities or composite scores.

2. Method

2.1. Participants

For this study, data collected within the Betula prospective cohort study were examined (Nilsson et al., 1997; Nilsson et al., 2004). This is a longitudinal study on memory, aging, and health which started in Umeå, Sweden, in 1988. Participants were drawn from the Swedish population registry (stratified by age and sex), and data have been collected over six test occasions, five years apart: 1988–1990 (T1), 1993–1995 (T2), 1998–2000 (T3), 2003–2005 (T4), 2008–2010 (T5), and 2013–2014 (T6). On each test occasion, participants visited the test locations over two sessions about one week apart. The first session mainly focused on health assessment, and the second on cognitive assessment (for further details, see Nilsson et al., 1997). The present study was approved by the Regional Ethics Committee (2016/101-31Ö), and all participants gave written informed consent in accordance with the Declaration of Helsinki.

2.1.1. Older sample

In this study, we considered Betula data from Samples 1 and 3 because for these two samples longitudinal cognitive data for up to four test occasions (T2–T5) were available. Main occupation was coded on the basis of T2 data. Data for cognitive measures and main lifetime occupation were available for 780 participants aged 65 years or older. Formal retirement age in Sweden was 65 years at study baseline (Olsson, 2011). To be included in the Betula study, the participants were required to be free of dementia. Dementia status was determined on the basis of neuropsychological testing, interviews conducted by trained nurses, and observations made at each test occasion. In addition, a geriatric psychiatrist performed evaluation of medical records for all participants every five years as additional screening in order to detect any additional participants who had had ongoing dementia at inclusion. None of the participants included in the present study had retrospectively been diagnosed with dementia at the latest follow-up (2017). The study sample had a mean age of 73.9 years ($SD = 6.9$) and included 336 men and 444 women from Samples 1 ($n = 369$) and 3 ($n = 411$). Mean number of years of education was 7.9 ($SD = 2.7$). Follow-up data were available for 502, 341, and 128 participants at the 5-, 10-, and 15-year follow-ups, respectively.

2.1.2. Middle-aged sample

To estimate general cognitive ability level at age 18, we used cognitive test scores retrieved from the Swedish military archives. These were gathered at draft boards (see Rönnlund, Sundström, & Nilsson, 2015) and linked to the Betula data in a subsample of men ($n = 260$; age 45–55 years) for whom measures of occupational complexity and episodic memory had been collected in middle-age (i.e., the Betula study; unfortunately no similar data were available for the older sample). Here we considered cross-sectional Betula data for episodic memory recall, as the major aim was to examine the relationship between occupational complexity before and after taking influences of early cognitive level into account. Mean age for the middle-aged sample was 49.9 years ($SD = 4.0$) and the men had a mean of 12.5 years of education ($SD = 4.1$).

2.2. Measures

2.2.1. Occupational cognitive complexity

Information about main lifetime occupation and work characteristics was collected as part of a questionnaire that was filled in by the participants at home between test sessions. In cases of an incomplete questionnaire, the participant completed it with the assistance of a nurse at the second test session. One trained research assistant first coded each main occupation according to the Swedish occupational classification. The occupations was later linked to version 3.0 of O*NET (2000) (http://www.onetonline.org/) through a Swedish database in which over 8000 participants' occupations had been given an O*NET classification (Theorell, Madison, & Ullén, 2019). Each O*NET occupation is coded from different dimensions describing characteristics of the work and worker. These dimensions are grouped under umbrella themes such as 'knowledge, skills, abilities', 'education, experience, training', and 'technology skills & tools'. Each theme includes several sub-areas containing many individual variables. In the present study, we used ten O*NET variables which were related to *level* of cognitive complexity at work and had been defined by O*NET to measure a talent or attribute that can help a person do a job.

Each item is rated from 0 to 7, with 7 indicating the highest level. The items identified as being related to cognitive processing were: 1) category flexibility, defined by O*NET as 'the ability to generate or use different sets of rules for combining or grouping things in different ways', 2) deductive reasoning, defined as 'the ability to apply general rules to specific problems to produce answers that make sense', 3) fluency of ideas, defined as 'the ability to come up with a number of ideas about a topic', 4) inductive reasoning, defined as 'the ability to combine pieces of information to form general rules or conclusions', 5) information ordering, defined as 'the ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules', 6) mathematical reasoning, defined as 'the ability to choose the right mathematical methods or formulas to solve a problem', 7) originality, defined as 'the ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem', 8) processing information, defined as 'compiling, coding, categorizing, calculating, tabulating, auditing, or verifying information or data', 9) thinking creatively, defined as 'developing, designing, or creating new applications, ideas, relationships, systems, or products, including artistic contributions', and 10) critical thinking, defined as 'using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems'. A sum score (for the older sample; $M = 30.0$, $SD = 6.3$, for the middle-aged sample; $M = 34.7$ $SD = 6.7$) was calculated on all ten individual items, with both skewness (0.35 and − 0.36) and kurtosis (−0.39 and 0.38) indicative of normally distributed data. Cronbach's alpha for the variables included in the composite was 0.96 for the older sample, and 0.96 for the middle aged sample.

2.2.2. Episodic memory recall

Three measures were used as indicators of episodic recall (see e.g., Nilsson et al., 1997; Nilsson et al., 2004). These measures have been used similarly in other studies (see e.g. Nyberg et al., 2020; Stenling et al., 2020), and a composite score based on all three has been shown to have good stability over time, with 5- and 10-year stability coefficients of 0.83 and 0.82, respectively (Rönnlund & Nilsson, 2006).

The first measure was action recall (AR). Participants did a task in which they carried out 16 actions (e.g., rubbing one's eye) within a time limit of 8 s per action. A metronome beep indicated the time. Directly after the actions had been executed, free recall followed, with a time limit for recall set to 2 min. Participants also performed a category-cued recall task of objects included in the actions previously performed. They were given a sheet with semantic categories referring to the objects presented among the actions (and sentences, see below). The time limit for recall was 3 min. The number of correctly recalled verb-noun actions and the total number of recalled objects/nouns served as total score for action recall (max = 32).

The second measure was sentence recall (SR). Participants performed a free recall task of 16 verb-noun sentences written on separate sheets and read aloud by the test leader. As for action recall, they were exposed to each stimulus for 8 s and the time for recall was 2 min. They also later performed a category-cued recall task of objects included in the sentences. The number of correctly recalled verb-noun sentences and the number of recalled objects/nouns served as score for sentence recall (max = 32).

The third measure was word recall (WR). Participants performed a free recall task of 12 nouns directly after they had been read aloud by the test leader at a pace of 2 s. The task was to recall as many nouns as possible, in any order, but also at a pace of 2 s. A metronome was used to indicate pace. Maximum time for free recall was 45 s, and number of recalled nouns (max = 12) served as score for word recall.

2.2.3. Early adult *g* (middle-aged sample)

Three cognitive measures in the Swedish Enlistment Battery (SEB) collected between 1954 and 1967 were included as indicators of early adult *g* (at age 18): (1) instructions (INS), which measures primary factor induction by asking participants to make markings on a sheet based on specified verbal instructions; (2) concept discrimination (CD), which involves classification of words; and (3) technical comprehension (TC), which includes a set of illustrated technical and physical problems (Carlstedt, 2000, unpublished). For each of these tasks, results were recorded in the form of stanine scores ($M = 5$, $SD = 2$). A *g* factor calculated on the basis of performance on these tasks has been shown to be a strong predictor of *g* in late adulthood (Rönnlund et al., 2015).

2.2.4. Control variables

Control variables used in the present study were age, sex (female coded as 0, male coded as 1), and years of formal education. These factors have all been related to performance in episodic recall in the Betula sample (Sörman, Ljungberg, & Rönnlund, 2018).

3. Statistical analysis

3.1. Older sample

First, we examined correlations between study measures. Unweighted composite scores were calculated for episodic memory (T1-T4) to interpret correlations with the general memory construct. Next, we tested longitudinal measurement invariance of the episodic memory construct across the four waves (baseline, 5 years, 10 years, and 15 years). Three measures (AR, SR, and WR) were used as indicators of a latent episodic memory recall construct across time. We specified and compared increasingly constrained models to examine longitudinal measurement invariance. Three types of longitudinal measurement invariance were examined: configural, metric, and scalar invariance (Little, 2013). Configural invariance indicates whether the same pattern of fixed and free parameters can be identified across time. No equality constraints were placed on the parameters in the configural invariance model. Next, a metric invariance model (i.e., equal factor loadings over time) was estimated to indicate whether the participants attributed the same meaning to the latent construct over measurement occasions. Finally, a scalar invariance model was estimated, with equality constraints being placed on the item intercepts across time. The scalar invariance model indicates whether the measures (test performance) have the same scaling over time. If scalar invariance is established, it is reasonable to interpret changes in the latent means across time as changes in the latent construct. The model fits of the increasingly constrained models were compared, and a decrease in CFI of ≥0.01 supplemented by an increase in RMSEA of ≥0.015 (cf. Chen, 2007) was used as an indication of non-invariance.

Finally, both conditional and unconditional growth curve models were tested. The unconditional model includes time as the level-1 predictor and is used to estimate if there are significant interindividual variance in initial cognitive status (i.e., intercept) and the amount of change or slope over time without consideration of explanatory variables. In the conditional model, intercept and slope are then conditioned by explanatory variables. This second-order latent growth model was used to investigate if occupational cognitive complexity and the control variables were associated with level (i.e., intercept) and time-related change (i.e., slope) across four time points (at baseline and at 5, 10, and 15 years post-baseline) in episodic memory recall in the sample of participants aged 65 years or older. The latent constructs for episodic memory recall were used as indicators of a latent intercept and a latent slope factor.

3.2. Middle-aged sample

To evaluate the possibility that level of early adult *g* is a potential factor behind the association of occupational complexity and episodic memory recall, we performed analyses based on the middle-aged sample. First, we examined correlations between study measures collected. Unweighted composite scores were calculated for episodic memory and early adult *g*. Second, structural equation models were tested on the subsample of middle-aged men (see 'Participants' section) to investigate the relationship between occupational cognitive complexity and episodic memory in midlife.

In the first model (Model 1), relationships between years of education after age 18 and occupational cognitive complexity were considered in relation to episodic recall in midlife. In the second model (Model 2), the direct effect of early adult *g* on occupational complexity was investigated without years of education included. In the third model (Model 3), both adult *g* and years of education were included to examine potential direct and indirect effects of *g* (e.g., on episodic memory via effects on education and occupational complexity). This three-step approach made it possible to examine the extent to which the relationships with occupational cognitive complexity changed as early adult *g* was added to the model. Indirect effects were examined using a bootstrap procedure involving 5000 samples and estimation of 95% confidence intervals of the estimates, using the percentile method (Tofighi & Kelley, 2019).

All models were analysed with SPSS and AMOS versions 26. Maximum likelihood estimation and a significance level of 0.05 was used. Model fit was evaluated by the χ^2 statistic divided by its degrees of freedom (*df*) along with its *p*-value, the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA) with a 90% confidence interval. Recommended cut-off criteria (see Kline, 2010; Hooper et al., 2008) used to estimate adequate model fit were as follows: CFI > 0.90, TLI > 0.90, RMSEA <0.08) and very good model fit (CFI > 0.95, TLI > 0.95, RMSEA <0.06.

4. Results

4.1. Older sample

Intercorrelations between study variables used in the analyses of the older sample are given in Table 1.

Among the study variables, age was found to be low to moderately correlated with episodic memory recall (r_{range} = −0.33 to −0.47) showing that higher age was negatively related to memory performance over all test occasions. Gender had a slight correlation with memory performance (r = −0.08 at T1, and r = −0.13 at T2) showing that being male was related to worse performance compared to females. Both education and occupational complexity had a low correlation with episodic recall at all test waves, with years of education (r_{range} = 0.24 to 0.33) overall being somewhat more related to episodic recall compared to occupational complexity. Occupational complexity showed a higher relationship with episodic recall at the last test wave (T4, r = 0.32) compared to earlier test waves (T1-T3, r_{range} = 0.11 to 0.18). Longitudinal interpretations from correlational analyses should however be made with some caution because they do not take into account individual change and may be biased by changes in sample size over test occasions.

A summary of performance in episodic memory recall confirmed that aging is characterised by a gradual decline, which is illustrated in Fig. 1.

Although the mean level of performance may seem to be relatively stable considering the complete data available at each test occasion (see Table 1), Fig. 1 however shows that there is a clear drop in performance taking into account the long-term cognitive trajectories of the participants before leaving the study.

Next, model fit indices of the increasingly constrained models included in the longitudinal measurement invariance testing are displayed in Table 2.

We did not observe a decrease in model fit after placing equality constraints on the factor loadings, and so metric invariance was supported. However, when placing equality constraints on the item intercepts we noted a decrease in CFI (ΔCFI = 0.026) and RMSEA (ΔRMSEA = 0.036), suggesting that one or more item intercepts were not invariant across time. The modification indices indicated that the model fit would improve if the intercept for the subject recall (SR) test at the first measurement point was estimated freely. Hence, we estimated a partial scalar invariance model where the item intercept of the SR test at the first measurement point was estimated freely; this model did not show a change in CFI and RMSEA that would suggest noninvariance when compared to the metric invariance model. These equality constraints were retained in the unconditional and conditional LGMs.

The model fits of the LGMs are presented in Table 2, and the results from the unconditional LGM are presented in Table 3. The variances of the intercepts were statistically significant, which suggests that there were meaningful between-person differences in episodic memory at baseline. The slope mean was negative and statistically significant, suggesting a decline over time. The variance of the slope was also

Table 1
Means (M), standard deviations (SD), and bivariate correlations among the study variables at baseline in the older-aged sample (n = 780).

Variable	*M*	*SD*	%	1	2	3	4	5	6	7	8
1. Age	73.92	6.90		–							
2. Male gender			43.1	−0.06	–						
3. Years of education	7.85	2.80		−0.13**	0.05	–					
4. Occupational complexity	30.03	6.28		−0.05	0.27**	0.44**	–				
5. Episodic recall - T1[a]	26.24	10.20		−0.47**	−0.08*	0.33**	0.18**	–			
6. Episodic recall - T2[a]	26.94	10.13		−0.45*	−0.13**	0.29**	0.14*	0.76**	–		
7. Episodic recall - T3[a]	25.49	11.13		−0.45**	−0.07	0.24**	0.11*	0.66**	0.76**	–	
8. Episodic recall - T4[a]	25.32	10.26		−0.33**	0.04	0.28**	0.32**	0.58**	0.61**	0.76**	–

[a] Unweighted composite score.
* $p < .05$.
** $p < .01$ (two tailed).

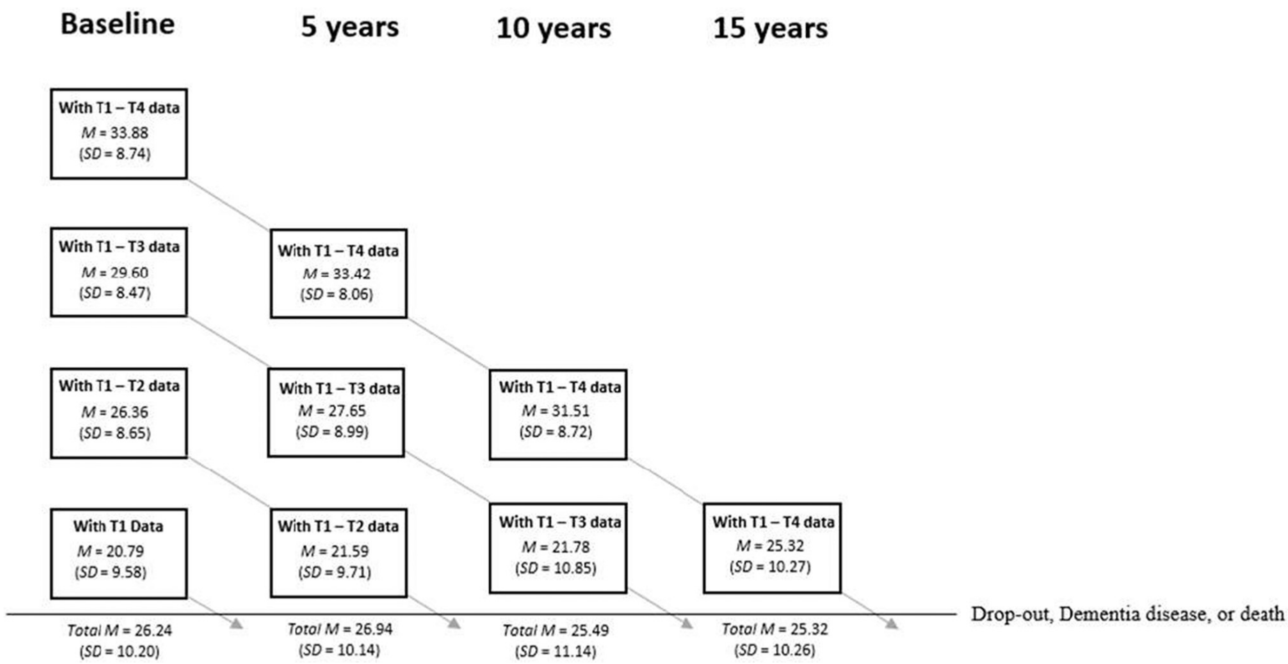

Fig. 1. Illustration of mean change in performance in episodic memory recall over time for participants with baseline, 5-year, 10-year, and 15-year follow-up data. Mean values (*M*) and standard deviations (*SD*) are calculated based on unweighted composite scores.

Table 2
Model fit indices of the longitudinal measurement invariance models and the unconditional and conditional growth curve models.

	χ^2	*df*	*p*	CFI	TLI	RMSEA	90% CI	
							LL	UL
Episodic memory recall:								
Configural	35.193	30	0.236	0.998	0.995	0.015	0.000	0.032
Metric (factor loadings)	38.734	36	0.347	0.999	0.998	0.010	0.000	0.028
Scalar (intercept)	112.626	42	0.000	0.973	0.949	0.046	0.036	0.057
Scalar (intercepts), partial	52.478	41	0.108	0.996	0.991	0.019	0.000	0.033
Unconditional LGM	89.891	46	0.000	0.983	0.971	0.035	0.024	0.046
Conditional LGM	153.771	86	0.000	0.978	0.965	0.032	0.024	0.040

Note: df = degrees of freedom, CFI = comparative fit index, TLI = Tucker-Lewis fit index, RMSEA = root mean square error of approximation, CI = confidence interval, LL = lower limit, UL = upper limit.

statistically significant, indicating differences between participants with regard to cognitive change over time. In the next step, we estimated the conditional LGM to investigate if the intercept (level of performance) and slope (time-related change) were related to age, sex, years of education, and occupational cognitive complexity. Model fit indices for the conditional model showed that CFI and TLI were above 0.95, RMSEA was below 0.06 (see Kline, 2010; Hooper et al., 2008), and χ^2/df was 1.79 ($p < .001$).

Standardized and unstandardized estimates for the associations between independent variables and episodic memory recall in the conditional growth curve model are presented along with standard errors, critical ratios, and *p* values in Table 4. Standardized estimates and R^2 values are also illustrated in Fig. 2.

Level of occupational cognitive complexity was positively related to higher level (intercept) of episodic recall ($\beta = 0.15$, $p < .001$), but the relation with change (slope) was weak and not statistically significant ($\beta = 0.03$, $p = .64$). Higher age was negatively related to both level ($\beta = -0.51$, $p < .001$) and change ($\beta = -0.48$, $p < .001$). Being male was associated with lower level of performance ($\beta = -0.19$, $p < .001$) compared to being female, but the relation between sex and change over time was not statistically significant ($\beta = 0.071$, $p < .271$). More years of education was related to higher level of performance ($\beta = 0.21$, $p < .001$), but also to a more negative change over time ($\beta = -0.15$, $p = .03$). The model explained 37% of the variance in the intercept and 25% of the variance in the slope.

4.2. Middle-aged sample

Intercorrelations between variables used in the analyses of the middle-aged sample are given in Table 5.

Early adult *g* was the factor that had the highest significant correlation with midlife episodic memory recall, indicative of a moderate correlation ($r = 47$). Years of education after age 18 ($r = 0.31$) and occupational complexity ($r = 0.26$) both had a small relationship with episodic recall, and age ($r = -0.14$) was weakly related to episodic memory. Early adult *g* was also moderately related to years of education ($r = 0.51$), and as well as significantly related to occupational complexity ($r = 0.35$), although this correlation was lower. Years of education had a somewhat higher relationship with occupational complexity ($r = 0.43$) than early adult *g* ($r = 0.35$).

Next, we investigated relations between occupational cognitive complexity and episodic memory recall in the middle-aged sample. Model 1, including occupational complexity together with years of formal education completed after age 18, demonstrated good model fit: CFI = 1.00, TLI = 1.09, RMSEA = 0.00, χ^2/df = 0.09, $p = .98$. Occupational complexity was related to episodic memory ($\beta = 0.21$, $p < .02$),

Table 3
Estimates of means and variances for unconditional growth curve models of episodic memory recall.

Model	→ INTERCEPT								→ SLOPE							
	Means				Variance				Means				Variance			
	Estimate	*S.E.*	*C.R.*	*p*	Estimate	*S.E.*	*C.R.*	*p*	Estimate	*S.E.*	*C.R*	*p*	Estimate	*S.E.*	*C.R.*	*p*
Episodic recall	14.297	0.193	74.051	<0.001	21.546	1.593	13.521	<0.001	−0.413	0.021	−19.567	<0.001	0.085	0.015	5.872	<0.001

Note: S.E. = standard error, *C.R.* = critical ratio.

Table 4
Relations between age, sex, years of education, and occupational cognitive complexity and level and change in episodic memory recall in the older-aged sample (n = 780).

	Episodic recall				
	β	*b*	*S.E.*	*C.R.*	*p*
Occupational cognitive complexity → I	0.150	0.111	0.026	4.244	<0.001
Occupational cognitive complexity → S	0.032	0.001	0.003	0.471	0.638
Age → I	−0.510	−0.344	0.022	−15.492	<0.001
Age → S	−0.477	−0.020	0.003	−7.621	<0.001
Male → I	−0.187	−1.761	0.316	−5.572	<0.001
Male → S	0.071	0.042	0.038	1.100	0.271
Education → I	0.208	0.858	0.142	6.043	<0.001
Education → S	−0.148	−0.038	0.017	−2.241	0.025

Note: I = intercept, S = slope, *β* = standardized regression weight, *b* = unstandardized regression weight, *S.E.* = standard error, *C.R.* = critical ratio.

and years of education after age 18 were predictive of both episodic recall ($\beta = 0.30$, $p < .001$) and occupational complexity ($\beta = 0.44$, $p < .001$). Model 2, including occupational cognitive complexity together with early adult *g*, demonstrated good model fit as well: CFI = 1.00, TLI = 1.02, RMSEA = 0.00, χ2/df = 0.88, $p = .56$. Critically, occupational complexity was no longer related to episodic memory ($\beta = 0.12$, $p = .14$), and early *g* were predictive of both episodic recall ($\beta = 0.60$, $p < .001$) and occupational complexity ($\beta = 0.38$, $p < .001$).

Finally, Model 3 (Fig. 3), which included both early *g* and years of formal education completed after age 18, showed good fit: CFI = 1.00, TLI = 1.00, RMSEA = 0.00, χ^2/df = 0.96, $p = .49$. Early adult *g* was, as before, strongly predictive of midlife level of episodic recall ($\beta = 0.60$, $p < .001$), education after age 18 ($\beta = 0.59$, $p < .001$), and future level of occupational cognitive complexity ($\beta = 0.19$, $p < .02$). Once more, occupational cognitive complexity was not associated with episodic memory recall in midlife ($\beta = 0.12$, $p = .14$), and education, unlike results for Model 1, showed no direct link to episodic memory ($\beta = -0.00$, $p = .98$). Tests of indirect effects indicated that education mediated the relation between early adult *g* and occupational cognitive complexity (*ab* = 0.19; 95% CI: 0.52, 1.21). The total effect (both direct and indirect) of early *g* on occupational complexity was $\beta = 0.38$.

In the Model 1 (with education), the predictor variables explained 19% of the variance in episodic recall. In Model 2 (with early adult g), the predictor variables explained 43% of the variance in episodic recall. In the third model (both early adult *g* and education included), 43% of the variance in episodic recall was accounted for. Additional details of the results from these models, with values for standardized and unstandardized estimates, standard errors, critical ratios, and *p* values, are presented in Table 6.

5. Discussion

5.1. Summary of findings

The present study investigated the association between occupational cognitive complexity and episodic memory recall in middle age and old age, in two sub-studies. In the first sub-study, we examined the extent to which history of occupational cognitive complexity was associated with level, as well as long-term (15-year) changes, in episodic memory in a sample of older adults (65 years and older). In the second sub-study, we examined the relationship between early adult intelligence, as reflected by Swedish military conscription tests taken at age 18, occupational cognitive complexity and episodic memory in men at midlife (45–55 years). Analyses of the middle-aged sample were conducted in order to investigate if *g* acts as a potential confound between occupational complexity and episodic memory recall.

The results pertaining to the older sample showed that a higher level

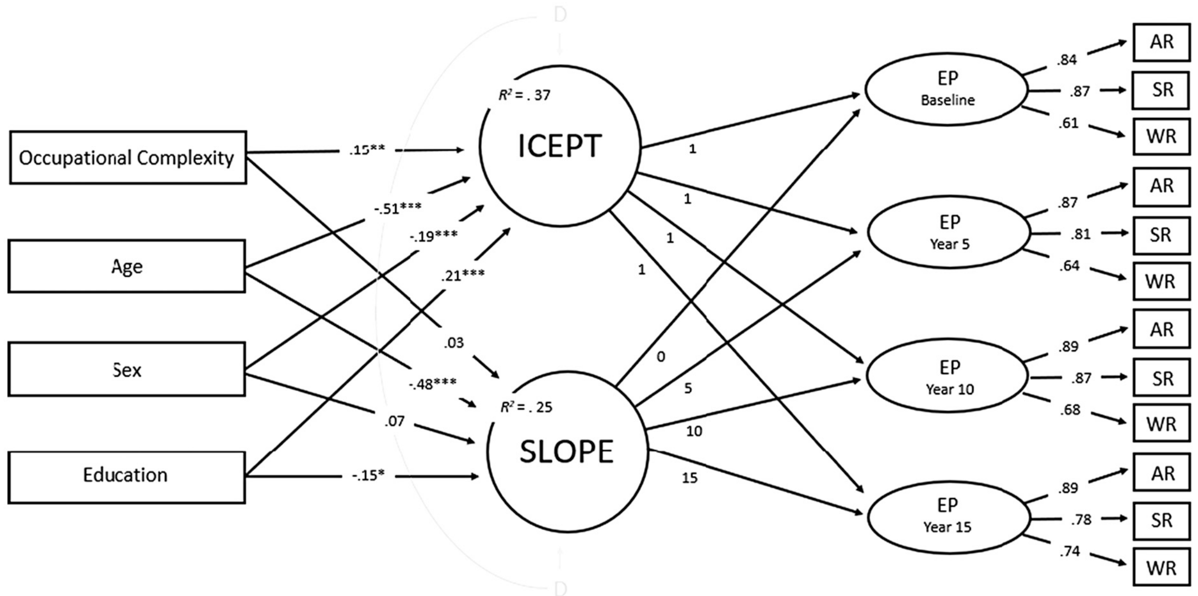

Fig. 2. Illustration of the second-order growth curve model with occupational cognitive complexity, age, sex, and years of formal education as independent variables in relation to intercept and slope of episodic recall. Latent variables of episodic recall performance were used at each test occasion. For readability, only regression paths along with standardized coefficients are presented.
Note: EP = episodic memory recall, AR = action recall, SR = sentence recall, WR = word recall.
*$p < .05$, **, $p < .01$, ***$p < .001$.

Table 5
Means (M), standard deviations (SD), and bivariate correlations among the study variables in the sample of middle-aged men (n = 260).

Variable	*M*	*SD*	1	2	3	4	5
1. Age	49.85	4.05	–				
2. Years of education	2.52	3.05	−0.19**	–			
3. Occupational complexity	34.68	6.73	−0.03	0.43**	–		
4. Episodic recall[a]	39.02	8.26	−0.14*	0.31**	0.26**	–	
5. Cognitive score, age 18	17.01	4.43	−0.06	0.51**	0.35**	0.47**	–

* $p < .05$.
** $p < .01$ (two tailed).
[a] Years of education after age 18.

of occupational cognitive complexity was associated with better episodic memory recall. By contrast, occupational complexity was not predictive of rate of change. Analyses of the midlife sample revealed similar results by demonstrating a significant positive association between occupational complexity and level of episodic memory. Of critical concern, the former association was not significant in analyses where early adult level of *g* was adjusted for. Hence, these results indicate that occupational cognitive complexity is associated with episodic memory level indirectly via the early *g* factor, and that higher occupational cognitive complexity does not reduce cognitive decline. Moreover, in the middle-aged sample early adult intelligence was found to be predictive of both future cognitive performance and level of occupational cognitive complexity.

In the middle-aged sample, we also investigated if education after the age of 18 mediates the relationship between early life *g* and occupational cognitive complexity and episodic memory recall. Results were consistent with this notion to the extent that early *g* showed an indirect effect (i.e. via education) apart from direct effect on occupational cognitive complexity. Critically, although *g* was strongly predictive of both future education and episodic recall, no indirect effect via education was found between early *g* and future cognition. Thus, mediation analyses confirmed that interindividual differences in memory ability in middle age is primarily related to ability level in youth, and is consistent with previous studies suggesting that additional education after young adulthood (*g* at age 20) has limited influence on late midlife cognitive functioning (see e.g., Kremen et al., 2019).

The finding of a relationship between occupational cognitive complexity and *level* of episodic memory performance in the middle-aged and the older sample (without adjustment for *g* in early adulthood) is in agreement with several other studies (Fisher et al., 2014; Lane et al., 2017; Pool et al., 2016; Potter et al., 2008; Smart et al., 2014). It should be noted that some of these studies did not find associations between all occupational complexity factors included in their analyses and cognitive performance after controlling for education. For example, no association could be established between complex work with data (Finkel et al., 2009) or things (Finkel et al., 2009; Smart et al., 2014) and cognitive outcomes in analyses controlling for education. Although our findings that occupational cognitive complexity is not related to rate of cognitive change or decline contradict some earlier studies (e.g., Andel et al., 2016; Bosma et al., 2003; Gajewski et al., 2010), including O*NET studies (e.g. Pool et al., 2016; Then et al., 2015) and one other study with episodic memory as outcome (Fisher et al., 2014), they are in in line with results by Lane et al. (2017). Our findings that occupational cognitive stimulation from work is not related to rate of cognitive change, or cognitive decline, also seems consistent with a recent study suggesting that high mental job demands do not reduce the risk of late-life dementia disorders (Sundström, Sörman, Hansson, Ljungberg, & Adolfsson, 2020). Furthermore, similar findings have been suggested for other forms of cognitive stimulation. For example, education (Seblova, Berggren, & Lövden, 2020) and book reading (Sörman et al., 2018) were found to be related to level but not to rate of decline in longitudinal analyses.

Presumably, the discrepancy in outcome can be explained by multiple factors, including such as differences in study sample, how cognitive complexity in occupation is measured, and cognitive tests. For instance, among the most recent O*NET studies mentioned, Pool et al. (2016) and Then et al. (2015) used global scores of cognitive

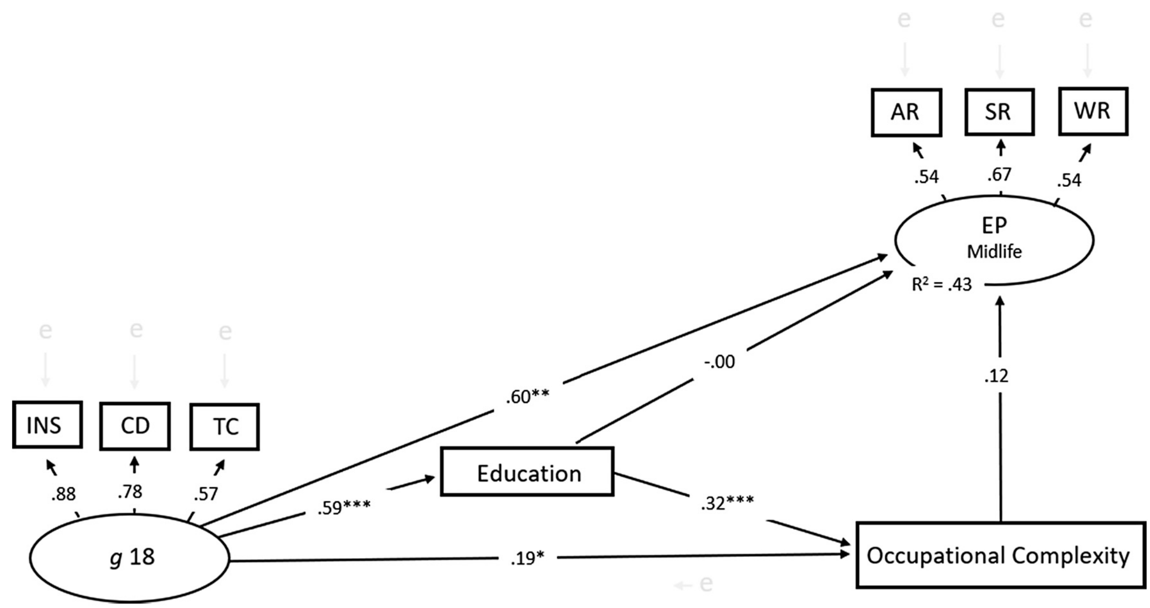

Fig. 3. Structural model with general ability factor at age 18 and years of education after age 18 in relation to occupational cognitive complexity and performance in episodic memory recall in midlife. Standardized estimates (βs) are presented.
g 18 = general ability at age 18, INS = instructions, CD = concept discrimination, TC = technical comprehension, Education = years of formal education after age 18, EP = episodic memory recall, AR = action recall, SR = sentence recall, WR = word recall.
$^*p < .05$, **, $p < .01$, $^{***}p < .001$.

Table 6
Associations with episodic recall in the middle-aged sample (n = 260) without control for early adult g (Model 1), without control for education (Model 2), and with control for both education and early adult g (Model 3).

	β	*b*	*S.E.*	*C.R.*	*p*
Model 1					
Occupational cognitive complexity → episodic recall	0.212	0.064	0.026	2.451	0.014
Education → episodic recall	0.304	0.202	0.061	3.313	< 0.001
Education → occupational cognitive complexity	0.435	0.959	0.124	7.757	< 0.001
Model 2					
Occupational cognitive complexity → episodic recall	0.115	0.037	0.025	1.482	0.138
Early g → episodic recall	0.602	0.868	0.163	5.312	<0.001
Early g → occupational cognitive complexity	0.382	1.719	0.298	5.758	<0.001
Model 3					
Occupational cognitive complexity → episodic recall	0.117	0.037	0.025	1.475	0.140
Education → episodic recall	−0.002	−0.002	0.066	−0.024	0.981
Education → occupational cognitive complexity	0.317	0.699	0.160	4.377	< 0.001
Early *g* → episodic recall	0.601	0.861	0.181	4.752	< 0.001
Early *g* → education	0.593	1.206	0.128	9.431	< 0.001
Early *g* → occupational cognitive complexity	0.193	0.865	0.354	2.445	0.014

Note: β = standardized regression weight, b = unstandardized regression weight, *S.E.* = standard error, *C.R.* = critical ratio. Model 1 included occupational cognitive complexity and years of education as independent variables in relation to performance in episodic memory recall. Model 2 included occupational cognitive complexity, years of education, and early adult intelligence as independent variables in relation to episodic memory recall.

functioning. Fisher et al. (2014), included episodic recall in relation to O*NET indicators, but they used immediate and delayed recall of nouns from words lists as measure of episodic memory. In the current study, three measures (word recall, action recall, sentence recall) as indicators of latent construct episodic recall. Latent constructs take into account the shared variance between observed variables, and also have the advantage of accounting for measurement error, and thereby increasing the possibility of being able to draw strong conclusions (Curran, Obeidat, & Losardo, 2010).

5.2. Theoretical contributions

As noted, early *g* accounted for much of the variance in future memory functioning, and seems to be critical factor also for level of cognitive performance in aging. As it seem, early level of *g* is likely also a critical factor for future choice or opportunity (see e.g., Dunlop & Savulescu, 2014) of occupation, with higher *g* in early adulthood being predictive of a more cognitively complex occupation. According to Salthouse (2006), it is likely that individuals with higher cognitive capacity generally engage in activities that are more mentally demanding.

From a theoretical perspective, these results can be understood from a pattern of preserved differentiation (see e.g., Bielak, 2010; Bielak et al., 2012; Salthouse, 2006; Salthouse et al., 1990). As suggested by Salthouse (2006), cognitive aging often seems to adhere to a pattern of preserved differentiation. Our findings appear to confirm such a pattern, at least when comparing individuals at different levels regarding history of working in occupations with high cognitive complexity. This more static pattern, with a view of relatively stable cognitive trajectories over the adult life span (at least from a between-individual perspective), may suggest that cognitive abilities are largely non-modifiable in adulthood and relatively established in earlier stages of life.

5.3. Practical contributions

What regards practical implications, results from this study do not suggest that occupational cognitive complexity is a factor that be used as intervention to promote episodic memory recall in aging. Given that brain plasticity is greater in younger ages it could be that cognitive stimulation should start in as early ages as possible because the older we get the harder it will be, on average, to change our life-course cognitive trajectories. Of course, we cannot rule out the possibility that cognitive stimulation has an immediate relative effect on cognitive functions after the age of 65 and when cognitive functions such as episodic memory on a general level often start to deteriorate (Bäckman et al., 2005).

With regard to cognitive stimulation after retirement age (65 years), a number of studies suggest that the beneficial effects of an active and cognitively stimulating lifestyle in old age should be understood from a perspective of short-term rather than long-term effects, which is in line with use-dependency theories (Almond, 2010). These theories suggest that activity levels and what we do during the aging process are of great importance. Such theories also overlap with 'disuse' theories (e.g., Christensen et al., 1996; Paggi & Hayslip, 1999), which posit that life events such as retirement, loss of a family member, or falling into loneliness can cause decreased cognitive stimulation, which in turn can have a negative impact on cognitive functions. Thus, it could be that it is the individual's continuous exposure to cognitive stimulation in old age that is decisive, rather than the development of a 'buffer' that is protective in the long term (see e.g. Nyberg & Pudas, 2019).

With regard a major covariate in the analyses, education, often considered as a core indicator of the cognitive reserve (for review and meta-analysis, see Sharp & Gatz, 2011; Valenzuela & Sachdev, 2006) we found no indication that it was protective against cognitive decline either. Results from this study rather demonstrate that education is highly correlated with early adult *g*, which is consistent with the idea that education can be viewed as a proxy of *g* (Deary & Johnson, 2010). Although education was positively related to intercept (level), it was, if anything, negatively related to slope (change) in episodic memory, suggesting that individuals with more years of formal schooling showed a more rapid decline. Although this relationship was relatively weak, it has been suggested that individuals with a higher reserve enter old age with a higher level of cognitive ability and have the ability to cope with ongoing dementia pathology (after incident dementia) for a longer period, but once a certain threshold is passed, an individual with high reserve has a more rapid decline (Barulli & Stern, 2013). It can only be speculated whether this was true in the present study sample, with the negative effect of education being driven by dementia pathology. However, previous studies on the Betula sample have reported no association between years of education and incident dementia (e.g., Sundström et al., 2020) and a recent meta-analysis found little support of such an association of education and cognitive change either (Seblova et al., 2020).

5.4. Limitations

Despite advantages, including access to a sub-sample with conscript data, use of multiple markers of memory, longitudinal measurements of the outcome variable over a long follow-up period, and fine-grained information about occupational cognitive characteristics, the study has several potential limitations that should be acknowledged. One concerns the fact that data on early adult cognitive ability were available for the middle-aged sample only; corresponding data for the older sample had been ideal for purposes of generalization. Given that the *g* factor (Rönnlund et al., 2015), as well as a similar episodic memory construct (Pudas & Rönnlund, 2019) showed high levels of stability, both in terms level and in terms of stability of inter-individual differences in the period from age 50 to 65 (cf., Bielak, 2010; Bielak et al., 2012; Salthouse et al., 1990), i.e. the gap in baseline age between the two sub-samples, we see little reason to expect that findings pertaining to the middle-aged sample would not apply to the older sample with regard to the influence of early adult g on the variables in present focus.

Moreover, parts of the model for the middle-aged sample included cross-sectional mediation analysis. Although we can assume a timeline from *g* at age 18 to years of education after age 18, recall and occupational complexity, we cannot conclusively determine the direction between midlife cognition and occupational complexity. Indeed, it has been argued that cross-sectional mediation analyses can produce biased estimates of longitudinal processes (Maxwell & Cole, 2007; Maxwell et al., 2011). On the other hand, the main conclusion based on our mediational model was that the relation between these factors was substantially weaker once *g* at age 18 was considered, and that early *g* was strongly related to future occupational cognitive complexity and cognitive ability.

Another limitation concerns the measurements of occupational cognitive complexity. We aimed to capture the level of cognitive complexity in different occupations based on the information available in O*NET. Even though, internal consistency for the O*NET were high for our complexity factor, and this factor was significantly related to other variables in the models, it is possible that other complexity factors may have revealed a different outcome. In addition, the occupational variables included in the present study are those described by O*NET as the cognitive demands related to the work. Although a similar procedure has been used in other studies (e.g., Fisher et al., 2014; Pool et al., 2016; Sundström et al., 2020), there is still no standard procedure of how to use O*NET variables to measure occupational cognitive complexity. In the current study, one trained research assistant coded each main occupation according to the Swedish occupational classification, and next linked it to version 3.0 of O*NET (2000). We cannot completely rule out the possibility that certain classifications would have benefited from the involvement of several raters.

Furthermore, occupations were categorized at the group level, but it seems likely that occupational cognitive complexity within the same occupational category will vary across workplaces. Also, we used classifications of occupations in 2000. Although from a time perspective this is closer to the baseline of this study (1993–1995) than current classifications would be, it is still possible that occupational cognitive complexity might have manifested itself differently over the years between baseline and the time when the classifications were created. In addition, we only had information about main lifetime occupation, and thus the length of time working in the occupation was not known. Such information, would have allowed us to investigate possible interaction effects between years in occupation and occupational complexity on episodic memory.

5.5. Future directions

In the present study, we aimed to capture level of cognitive complexity. However, it is possible that other factors related to work may have revealed a different outcome. For instance, previous research suggests that engagement in social activities (e.g., Glei et al., 2005) and social relations (Kuiper et al., 2016) may reduce the risk of cognitive decline. O*Net contains information about social aspects of different occupations, and it is possible that the degree to which individuals' jobs demand interpersonal interactions has implications for their cognitive aging. Future cognitive aging research should thus aim to capture such elements of individuals' occupations.

In this study, we focused on episodic memory recall, but it is possible that associations we observed generalize to other cognitive abilities. Previous studies have, for instance, found cross-sectional associations between occupational cognitive complexity and performance in tasks measuring executive functions (Sörman et al., 2019) and working memory (Van der Elst et al., 2012). Such aspects of cognition together with speed of processing are examples of cognitive abilities known be related to change in normal aging (see e.g., Murman, 2015). In the Betula study, we do not have access to long-term (15 year) data on these domains, and future studies will have to determine the extent to which the present patterns generalize across other cognitive domains.

Finally, as demonstrated by this study, future studies must consider the importance of *g* when investigation the influence of occupational complexity on cognitive aging.

5.6. Conclusions

In conclusion, the results of this study suggested that a history of higher occupational cognitive complexity was related to level of episodic memory recall in both a middle-aged (45–55 years) and an older-aged sample ($\geq$ 65 years) but unrelated to rate of longitudinal change, which is consistent with a pattern of preserved differentiation. Consideration of early adult intelligence showed that it was a predictor of future occupational complexity (both directly and indirectly via years of education) as well as midlife level of episodic recall. Adjustment for *g* even attenuated the relationship between occupational cognitive complexity and memory to the extent that is was no longer significant, suggesting that it is a major antecedent factor both of future levels of work complexity and memory level in advanced age.

Declarations of interest

None.

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