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## Life-course socioeconomic conditions and cognitive performance in older adults: a cross-cohort comparison

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### ABSTRACT

**Objectives:** Socioeconomic disadvantage predicts the level of cognitive performance in old age, but findings have been mixed for trajectories of performance. This study examined associations between life-course socioeconomic conditions, including social mobility, and cognitive performance assessed in terms of level and change, across multiple cognitive domains in two independent cohorts of older adults.

**Methods:** Data were from two Swiss population-based cohorts: CoLau|PsyCoLau ( $N = 1210$ , mean age 72 years) and *Vivre/Leben/Vivere* ( $N = 993$ , mean age 75 years). Verbal fluency, processing speed, cognitive flexibility, memory, and global cognitive performance were assessed at two time points, each spaced 6 years apart. Associations between socioeconomic conditions (father’s occupation, parental education, own education, own occupation, household income, and social mobility) and cognitive performance were examined within each cohort, and using pooled data. Covariates included health behaviors, comorbidities, and depressive symptoms.

**Results:** Across cohorts, socioeconomic disadvantage predicted a lower level of performance across different cognitive domains, including processing speed, verbal fluency, and memory. Moreover, individuals who experienced life-course socioeconomic disadvantage performed worse than those who experienced upward social mobility. Associations between socioeconomic disadvantage and cognitive decline were less consistent.

**Conclusion:** Life-course socioeconomic conditions predict performance level across different cognitive domains, and, to a lesser extent, performance trajectories.

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life course; socioeconomic disadvantage; social inequalities; cognition; cognitive performance; cognitive reserve

## Introduction

Cognitive performance declines with age, for example, on tasks of processing speed, working memory, and executive function (Harada et al., 2013). However, there are substantial individual differences in both the level of cognitive performance in old age and the rate of cognitive decline. Maintaining cognitive health in later life is required for individuals to function independently, and to have quality of life (Tucker-Drob, 2011); thereby minimising costs to society (Wimo et al., 2017). A major goal of aging-related research is, therefore, to understand how individual differences in cognitive health emerge. According to cognitive reserve theories, living in an enriched environment, which includes, for example, higher levels of educational attainment and engagement in complex occupations, can compensate for age-related neurological loss and cognitive decline (Ihle et al., 2018; Stern, 2009).

Indeed, socioeconomic disadvantage, as measured by level of education, occupation, or income has consistently been associated with overall lower levels of cognitive performance in old age (Opdebeeck et al., 2016). However, socioeconomic differences in cognitive decline have been inconsistent, with

null, negative, and positive associations having been reported (Aartsen et al., 2019; Cadar et al., 2017; Lövdén et al., 2020; Steptoe & Zaninotto, 2020). These inconsistencies may partly be explained by statistical power issues in some studies, limited consideration of potential moderating factors (Sauter et al., 2021), and/or differences between cohorts, including differences in the socio-cultural context, and in the measurement of socioeconomic disadvantage.

Measures of education generally reflect earlier life experiences and abilities (Branigan et al., 2013), while occupation and income-based measures also reflect access to resources in mid-life. Research that uses a life-course approach can examine the individual and combined effects of childhood and adulthood socioeconomic conditions on the aging process (Ben-Shlomo & Kuh, 2002); and therefore, provides a more complete picture of how risk exposures affect cognitive health. Previous studies using a life-course approach indicate that associations between childhood socioeconomic conditions and cognitive performance are at least partly explained by socioeconomic conditions in adulthood (Aartsen et al., 2019; Greenfield et al., 2021; Lyu & Burr, 2016).

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Social mobility, namely transitions from socioeconomic advantage to disadvantage and vice versa (Ben-Shlomo & Kuh, 2002) may also be important for later-life cognitive performance. One study found that individuals who experienced a stable-low socioeconomic trajectory were epigenetically older than those who experienced an upward socioeconomic trajectory (Fiorito et al., 2017), suggesting some degree of reversibility of the effects of disadvantaged childhood conditions. Earlier cross-sectional studies of middle-aged and older adults found that upward social mobility predicted a higher level of cognitive performance than those who experienced a stable-low socioeconomic trajectory (Luo & Waite, 2005; Turrell et al., 2002). Just one known previous study examined associations between social mobility and change in memory performance in a sample of 388 older adults, and found no association (Staff et al., 2018).

Associations between socioeconomic conditions and cognitive performance may also be domain specific (Opdebeeck et al., 2016). Existing studies have tended to focus on memory and the executive function verbal fluency, with fewer findings reported for other cognitive domains (Seblova et al., 2020). Recent research found that socioeconomic disadvantage predicted poorer prospective memory performance, but there were no associations with subjective memory complaints (Künzi et al., 2021).

The present study will further examine associations between life-course socioeconomic conditions and cognitive performance by addressing gaps in the literature. First, the study will examine whether transitions from socioeconomic disadvantage to advantage, namely social mobility, predict both the level of and change in cognitive performance. Second, the assessment of various cognitive domains that tend to decline with age, including both measured and perceived cognitive function, makes it possible to see whether associations between socioeconomic conditions, including social mobility, and cognitive performance are domain specific. Third, the cross-cohort design makes it possible to see whether the results are generalizable across two independent cohorts. Associations will be examined with consideration of key covariates including health behaviors, which may contribute to socioeconomic differences in aging (Allen et al., 2017).

## Methods

### Samples and design

Two Swiss population-based cohorts were compared. The CoLaus|PsyCoLaus study is a longitudinal cohort of individuals aged 35 to 75 years at recruitment living in the city of Lausanne, Switzerland (Firmann et al., 2008). There have been three completed waves of data collection so far: baseline (2003 to 2006;  $N=6733$ ), first follow-up (2009 to 2012;  $N=5064$ ), and second follow-up (2014 to 2017;  $N=4,881$ ). At first and second follow-up, a cognitive test battery was administered to participants aged 65 years and above. In total, 1210 individuals provided cognitive data at first follow-up (mean age = 71.60,  $SD = 4.71$ ), and 997 individuals provided cognitive data at both first and second follow-up. Compared to those who were lost to second follow-up ( $N=213$ ), the participants included in the longitudinal analysis ( $N=997$ ) were younger ( $M=71.23$  vs. 73.32 years,  $p<0.001$ ), a greater proportion were women (60.8% vs. 44.6%,  $p<0.001$ ), and a smaller proportion were smokers (13.0% vs. 21.5%,  $p=0.002$ ), had comorbidities (38.0% vs. 49.3%,  $p=0.002$ ), and cognitive

impairment (Mini State Mental Examination Score  $<27$ ; 5.5% vs. 14.0%,  $p<0.001$ ). There were no differences in educational level or last known occupational position.

The Vivre/Leben/Vivere study (VLV) is a cohort of individuals aged 65 years and older living in the Swiss cantons of Geneva and Valais (French-speaking), Bern and Basel (German-speaking), and Ticino Switzerland (Italian-speaking) (Ludwig et al., 2014). Participants were recruited in 2011 ( $N=3080$ ) and followed up in 2017 ( $N=1059$ ). At follow-up, participants completed a comprehensive cognitive test battery. In total, 993 individuals provided cognitive data at follow-up, and all of these individuals provided data on a smaller set of cognitive measures at baseline (mean age = 74.58,  $SD = 6.60$ ). Compared to those who were lost at follow-up ( $N=2087$ ), the participants included in the longitudinal analysis ( $N=993$ ) were younger ( $M=74.6$  vs. 80.2 years;  $p<0.001$ ), and a smaller proportion had a low education level (10.1% vs. 23.4%,  $p<0.001$ ), a low occupational position (15.1% vs. 28.7%,  $p<0.001$ ), and comorbidities (59.6% vs. 65.7%,  $p=0.001$ ). There were no differences in the distribution of gender or smoking status.

The CoLaus|PsyCoLaus study was approved by the Institutional Ethics Committee of the University of Lausanne, which later became the Ethics Commission of Canton Vaud (project reference numbers: 16/03, 33/09, 26/14); the VLV study was approved by the ethics commission of the University of Geneva (project reference numbers: CE\_FPSE\_14.10.2010, CE\_FPSE\_05.04.2017). All participants provided written informed consent.

## Measures

### Socioeconomic conditions

Childhood socioeconomic conditions were assessed using father's occupation and highest parental education level, which were available in both cohorts. Father's occupation was categorized using the 3-class model of the European Socioeconomic Classification (ESEC) framework (Rose & Harrison, 2007): lower (lower clerical, services, and sales workers, skilled workers, semi-skilled and unskilled workers), intermediate (small employers and self-employed, farmers, lower supervisors and technicians), and higher (higher professionals and managers, higher clerical, services, and sales workers). Highest parental education level was categorized as: lower (none or compulsory school), intermediate (secondary school or apprenticeship), and higher (university). In CoLaus|PsyCoLaus, there was also information on financial conditions during childhood: family car, TV, dishwasher, telephone, and home ownership, having enough heat, participation in a cultural/social association, going on regular holidays, and employing a maid during the participant's childhood were summed (range 0–9) and categorized into tertiles.

Adulthood socioeconomic conditions were assessed using highest education level, last known occupational position, and household gross monthly income. Education level was categorized as: lower (primary or lower secondary school education), intermediate (upper secondary school education or apprenticeship), and higher (tertiary education, including any degree or training after secondary school) (UNESCO, 2011). Occupational position was categorized in the same way as father's occupation. Information on household gross monthly income was collected using categories, which slightly differed between cohorts. The data were harmonized using cohort-based tertiles.

Social mobility trajectories were calculated using father's occupational position during childhood and participant's last known occupation, and categorized as: stable-low (lower classification in childhood and adulthood), downward (higher classification in childhood and intermediate or lower classification in adulthood, or intermediate classification in childhood and lower classification in adulthood), stable-mid (intermediate classification in childhood and adulthood), upward (lower classification in childhood and intermediate or higher classification in adulthood, or intermediate classification in childhood and higher classification in adulthood), and stable-high (higher classification in childhood and adulthood).

### Cognitive performance

In both cohorts, verbal fluency was assessed using letter (phonemic) and category (semantic) fluency tasks. In VLV, these tasks were carried out using the Cognitive Telephone Screening Instrument (COGTEL, (Kliegel et al., 2007)). The verbal fluency score was the total number of words beginning with the named letter/belonging to the named category correctly identified in the allocated time (60 s in VLV; 120 s in CoLaus|PsyCoLaus).

Processing speed was assessed using the Trail Making Test part A (TMT A; (Reitan, 1958)) in VLV, and the Stroop color condition (Golden, 1978) in CoLaus|PsyCoLaus. TMT A completion time was the time in seconds needed to correctly connect the numbers 1 to 25 in ascending order. Stroop processing speed scores were the time in seconds needed to correctly name the colors ('xxxx' printed in colored ink).

In VLV, cognitive flexibility was measured using the Trail Making Test part B (TMT B; (Reitan, 1958)) adjusted for processing speed (TMT ratio score, B/A). TMT B completion time was the time in seconds needed to correctly connect the numbers 1 to 13 in ascending order, and the letters A to L in alphabetic order while alternating between numbers and letters (i.e. 1-A-2-... 12-L-13). In CoLaus|PsyCoLaus, cognitive flexibility was measured using the verbal fluency category switching condition (animals/fruit) adjusted for scores on category fluency. Residual scores for category switching accuracy (number of correct switches) were obtained by adjusting for the number of correct responses across the category fluency trials.

Inhibitory control was assessed in CoLaus|PsyCoLaus using the Stroop color-word task. Participants had to name the color of the ink while inhibiting the reading of the word (e.g. the word 'green' printed in the color 'red'). An interference index was calculated as time to complete the interference task/time to name the colors.

In VLV, verbal short-term memory was assessed with a verbal paired-associate memory test (immediate recall) of the Wechsler Memory Scale-Revised from the COGTEL (Kliegel et al., 2007). Short-term memory scores were the total number of correctly completed word pairs (min = 0; max = 8). Verbal long-term memory was assessed using the same word pairs in a delayed-retrieval test at the end of the procedure. In CoLaus|PsyCoLaus, verbal short- and long-term memories were assessed using the Grober and Buschke Double Memory Test (Buschke et al., 1997). Verbal short-term memory was the number of words freely recalled after a short interference task (counting backwards) (min = 0; max = 6). Verbal long-term memory was the number of words freely recalled after 20 min.

Subjective cognitive complaints were assessed using the Cognitive Complaint Questionnaire (CCQ; (Anterion et al., 2003)) in CoLaus|PsyCoLaus. The CCQ consists of 10 yes/no

questions about subjective cognitive changes over the last six months (e.g. 'do you feel like your memory is worse in comparison to your peers?'). Subjective cognitive decline is considered present based on the number of positive answers to the 10 questions. In VLV, participants were asked 'In everyday life, does your memory ever play tricks on you?' (0 = never; 3 = always).

Global cognition was assessed using the Mini Mental State Examination (MMSE; both cohorts) and the Clinical Dementia Rating (CDR; CoLaus|PsyCoLaus). MMSE scores range from 0 to 30, with higher scores indicating better performance (Folstein et al., 1975). Scores were categorized to indicate no cognitive impairment (27 to 30) or some cognitive impairment (<27). Individuals with MMSE scores lower than 21 (indicating moderate or severe impairment) were not included in the analyses. CDR scores range from 0 to 5, with higher scores indicating greater impairment (Morris, 1993). In CoLaus|PsyCoLaus, scores were categorized to indicate the absence (0) or presence (0.5 or 1) of mild cognitive impairment.

Longitudinal cognitive data were available for processing speed, cognitive flexibility, cognitive complaints, and global impairment in VLV, and all cognitive domains in CoLaus|PsyCoLaus.

The cognitive tests used in CoLaus|PsyCoLaus and VLV have demonstrated acceptable reliability and validity (Grober et al., 2009; Harrison et al., 2000; Ihle et al., 2017; Morris, 1997; Siegrist, 1997; Tombaugh & McIntyre, 1992; Wagner et al., 2011).

### Covariates

Covariates included self-reported cardiovascular disease, diabetes, and hypertension (none, one or more), smoking status (smoker, non-smoker), frequency of alcohol consumption (rarely or never drinks, weekly drinker, daily drinker), physical inactivity (active, inactive), and depressive symptoms (categorized into tertiles). Physical inactivity was defined as not engaging in any moderate or vigorous activity (such as running, tennis, football, bicycling) for at least 20 minutes each week in CoLaus|PsyCoLaus, and for at least 30 minutes each week in VLV. Depressive symptoms were assessed using the Center for Epidemiological Studies-Depression scale (CES-D, (Radloff, 1977)) in CoLaus|PsyCoLaus, and using 10 items from the Wang Self-Assessing Depression Scale (SADS, (Wang et al., 1975)), and 3 items from the General Health Questionnaire (GHQ, (Goldberg et al., 1997)) in VLV. For both cohorts, a mean score was calculated and then categorized into tertiles.

All covariates were assessed at baseline apart from physical inactivity in VLV, which was assessed at follow-up only.

### Statistical analysis

A total of 2203 participants (1210 from CoLaus|PsyCoLaus, 993 from VLV) with available socioeconomic and cognitive data were included in the analyses. Missing data on covariates (depressive symptoms and health behaviors) were imputed through multivariate imputation by chained equations (20 imputed data sets).

Associations between life-course socioeconomic conditions and cognitive performance were first examined within each cohort. The verbal fluency, memory, and global cognition data were then pooled (since these domains were measured in the same way across cohorts) to further examine patterns of performance across different social mobility trajectories.

Cross-sectional associations were examined using linear regressions for continuous cognitive outcomes, and logistic

regressions for categorical cognitive outcomes. Continuous cognitive outcomes were standardized using Z-scores (to have a mean of 0 and a standard deviation (SD) of 1). Univariate associations were examined between each measure of childhood and adulthood socioeconomic conditions and each cognitive outcome separately (adjusting for sex, age, and age squared, to take into account potential non-linear effects of age on cognitive performance (Verhaeghen & Salthouse, 1997)). A second series of models additionally included health behaviors (smoking, alcohol consumption, and physical activity), comorbidities, and depressive symptoms as covariates.

Longitudinal associations were examined using standardized change scores for continuous cognitive outcomes, to provide a common metric across outcomes: the sex-specific SD of each continuous cognitive variable at baseline was calculated, and both the baseline and follow-up values were divided by this number. Change scores were the difference between the two standardized values. Linear regressions were used to analyze associations between each measure of childhood and adulthood socioeconomic conditions and difference scores, and logistic regressions were used for categorical cognitive outcomes. The models controlled for the same covariates as in the cross-sectional analyses plus the baseline level of the outcome measure.

The socioeconomic measures were entered as continuous predictors, as there were no departures from a linear trend ( $p \geq 0.05$ ). For all socioeconomic measures, the highest (most advantaged) socioeconomic group was used as the reference.

For each set of analyses, the False Discovery Rate (FDR) correction was applied to take into account multiple testing (Benjamini & Hochberg, 1995). Statistical analyses were performed with Stata® version 15 (Stata Corporation, College Station, TX, USA) and Python 3.7.1, Pandas package (DOI: 10.5281/zenodo.4681666).

## Results

Table 1 includes baseline descriptive statistics for the CoLaus|PsyCoLaus and VLV samples. Compared to CoLaus|PsyCoLaus participants, VLV participants were older, had a higher education level, a more skilled last known occupational position, a more advantaged social mobility trajectory, and consumed alcohol less frequently; a smaller proportion were smokers, and a greater proportion had comorbidities and cognitive impairment (MMSE scores < 27). There was also a more equal gender distribution in the VLV cohort than the CoLaus|PsyCoLaus cohort. There was no significant difference between cohorts in terms of physical activity level.

Figure 1 shows the associations between life-course socioeconomic conditions and cognitive performance (level and decline) within each cohort, when adjusting for age, age squared, and sex only (see Tables S1 and S2 for values). Across cohorts, individuals who experienced more disadvantaged socioeconomic conditions in childhood and adulthood had a poorer level of cognitive performance than those who experienced advantaged socioeconomic conditions. This association was apparent for performance on processing speed, verbal fluency, inhibitory control (CoLaus|PsyCoLaus), memory, and global cognitive tasks. There was no association between socioeconomic conditions and cognitive flexibility in either cohort, and there were few associations with subjective cognitive complaints. Associations were apparent for different socioeconomic indicators, but most consistent for education level. For social

mobility, associations were apparent for verbal fluency, memory, and inhibitory control in CoLaus|PsyCoLaus, and for processing speed, verbal fluency, and global cognitive impairment in VLV (see Table 2 for values).

In both cohorts, socioeconomic disadvantage was associated with greater odds of global cognitive impairment at follow-up, adjusting for cognitive impairment at first assessment. In CoLaus|PsyCoLaus, lower educational level was associated with greater decline in inhibitory control. These associations followed a linear trend; decline in inhibitory control was 0.48 standard deviations greater among those with a lower education level compared with those who had a higher education level (see Figure S1). Socioeconomic disadvantage, including social mobility, was also associated with greater decline in verbal fluency and short-term memory at the  $p < 0.05$  level, but these associations did not hold when correcting for multiple tests (see Tables 2, S2 and S3). The pattern of associations within each cohort largely remained the same when additionally adjusting for health behaviors, comorbidities, and depressive symptoms (see Figure S2, and Tables S3 and S4 for values).

Results of the pooled analysis are shown in Figure 2. Participants who experienced a stable-low trajectory had poorer level of verbal fluency (-0.75 (-1.03, -0.46),  $p < 0.001$ ), poorer short- and long-term memory performance (-0.46 (-0.76, -0.17),  $p = 0.002$ ; -0.44 (-0.73, -0.15),  $p = 0.003$ ), and greater odds of cognitive impairment at first assessment (4.09 (1.98, 8.44),  $p < 0.001$ ) and follow-up (3.10 (1.48, 6.48)  $p = 0.003$ ) (adjusting for cognitive impairment at first assessment) than those who experienced a stable-high trajectory. The associations followed a dose-response pattern ( $p$  for trend  $\leq 0.001$ ). When using the stable-low trajectory as the reference group, those who experienced upward social mobility consistently performed better than those who experienced a stable-low trajectory ( $p$ -values  $\leq 0.01$ ).

## Discussion

Consistent with previous research, this study found that socioeconomic disadvantage across the life course, including social mobility, was associated with a lower level of cognitive performance in older adults. The associations followed a dose-response pattern, emerged across different cohorts and across different cognitive domains, including processing speed, executive functions, and memory, and persisted when taking into account the influence of health behaviors and indicators of health status. Associations between socioeconomic disadvantage and longitudinal cognitive decline were also apparent, but less consistent than those observed for the level of cognitive performance.

Of the different socioeconomic indicators, educational level was the most consistently associated with performance level across different cognitive domains. This finding concurs with a meta-analytic review (Opdebeek et al., 2016), and suggests that different proxy measures for cognitive reserve show some differences in their association with cognitive function. As socioeconomic experiences are inter-related, experiences across the lifespan likely predict cognitive function in combination as well as individually.

The links between socioeconomic disadvantage and memory performance were less consistent in the VLV cohort than the CoLaus|PsyCoLaus cohort. One possible explanation is the age difference between cohorts as memory was assessed at

**Table 1.** Descriptive statistics for the CoLaus|PsyCoLaus and VLV samples at baseline.

	CoLaus PsyCoLaus (N = 1210)	VLV (N = 993)	CoLaus PsyCoLaus vs. VLV
	M (SD) or % (n)	M (SD) or % (n)	P difference
Childhood socioeconomic conditions			
Father's occupational position			<0.001
Low	27.75 (260)	39.02 (357)	
Intermediate	56.99 (534)	39.13 (358)	
High	15.26 (143)	21.86 (200)	
Adulthood socioeconomic conditions			
Highest education level			<0.001
Primary	18.02 (218)	10.11 (99)	
Secondary	67.77 (820)	52.20 (511)	
Tertiary	14.21 (172)	37.69 (369)	
Last known occupational position			<0.001
Low	21.55 (117)	15.05 (140)	
Intermediate	58.20 (316)	53.23 (495)	
High	20.26 (110)	31.72 (295)	
Social mobility trajectory <sup>a</sup>			<0.001
Low-stable	7.38 (33)	8.42 (72)	
Downward	20.81 (93)	14.27 (122)	
Intermediate-stable	33.33 (149)	22.57 (193)	
Upward	30.20 (135)	42.81 (366)	
High-stable	8.28 (37)	11.93 (102)	
Cognitive performance			
Processing speed			
Stroop word and color <sup>b</sup> , seconds	28.25 (94.12)	–	
Trail making test A, seconds	–	55.72 (24.00)	
Verbal fluency <sup>c</sup> , words	49.80 (14.23)	24.80 (8.32)	
Verbal memory <sup>d</sup> , words			
Short-term memory	30.02 (6.75)	3.09 (2.09)	
Long-term memory	11.47 (2.76)	4.28 (2.20)	
Cognitive flexibility			
Verbal fluency switching, words	7.13 (2.72)	–	
Trail making test B/A	–	2.26 (0.76)	
Inhibitory control			
Stroop interference index <sup>e</sup>	2.10 (0.70)	–	
Cognitive complaints			
Subjective decline, CCQ	19.07 (214)	–	
No subjective decline, CCQ	80.93 (908)	–	
Single item, 0 = never – 3 = always	–	1.02 (0.54)	
Global impairment (MMSE)			<0.001
Impairment (< 27)	6.88 (80)	17.04 (169)	
No impairment (27 – 30)	93.12 (1082)	82.96 (823)	
Global impairment (CDR)			
Impairment (≥ 0.5)	52.84 (595)	–	
No impairment (0)	47.16 (531)	–	
Covariates			
Age	71.60 (4.71)	74.58 (6.60)	<0.001
Gender			<0.001
Men	42.07 (509)	50.76 (504)	
Women	57.93 (701)	49.24 (489)	
Comorbidities <sup>f</sup>			<0.001
1 or more	40.00 (484)	59.62 (592)	
None	60.00 (726)	40.38 (401)	
Depressive symptoms <sup>g</sup>	10.29 (8.23)	0.65 (0.33)	
Current smoking status			0.002
Smoker	14.44 (172)	9.99 (99)	
Non-smoker	85.56 (1019)	90.01 (892)	
Alcohol consumption, frequency			<0.001
Daily drinker	38.09 (371)	37.11 (367)	
Weekly drinker	40.76 (397)	21.64 (214)	
Rarely or never drinks	21.15 (206)	41.25 (408)	
Physical activity			0.400
Inactive	31.57 (376)	29.89 (289)	
Active	68.43 (815)	70.11 (678)	

Note:  $\chi^2$  tests were used to compare categorical variables across cohorts; t-tests were used to compare continuous variables; CCQ = Cognitive Complaints Questionnaire, MMSE = Mini State Mental Examination, CDR = Clinical Dementia Rating.

<sup>a</sup>calculated using father's occupational position during childhood and participant's last known occupational position, <sup>b</sup> time to correctly name the colors, <sup>c</sup> letter (phonemic) and category (semantic) fluency tasks – number of words correctly produced in 1 minute (VLV) and 2 minutes (CoLaus|PsyCoLaus), <sup>d</sup> Grober and Buschke Double Memory Test (CoLaus|PsyCoLaus)/COGTEL (VLV), <sup>e</sup> time to complete word-color interference task/time to complete simple color naming task, <sup>f</sup> presence of hypertension, cardiovascular disease, and diabetes, <sup>g</sup> CES-D (0–60) (CoLaus|PsyCoLaus)/Wang Self-Assessing Depression scale and General Health Questionnaire (0–3) (VLV).

follow-up only in VLV, when participants were significantly older (81 years on average compared to 75 years at first assessment). Research indicates that social inequalities in aging are reduced

at older ages (Crimmins et al., 2009), since higher-risk individuals die at younger ages, resulting in greater similarity among those who reach old age.

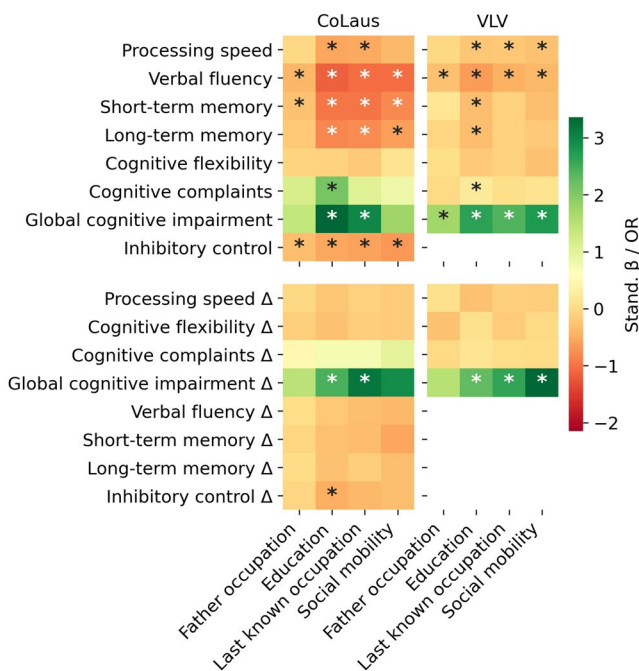
Consistent with previous research, there were associations between socioeconomic disadvantage and executive functions including verbal fluency (both cohorts) and inhibitory control (CoLaus|PsyCoLaus), but there were no associations with cognitive flexibility. Previous studies examining the association between socioeconomic disadvantage and cognitive flexibility have tended to use measures that do not take into account the influence of processing speed, such as TMT B completion time (e.g. Welsh-Bohmer et al., 2009). The present study used two different indicators of cognitive flexibility, each adjusted for processing speed (namely the TMT B/A ratio and verbal fluency category switching), suggesting that previously reported associations may have been due to differences in processing speed, or other related domains (Oosterman et al., 2010).

Education level was the only significant predictor of subjective memory complaints in each cohort, and this association

was substantially reduced when taking into account depressive symptoms. These findings replicate those of (Künzi et al., 2021), using a more comprehensive measure of memory complaints (Cognitive Complaints Questionnaire) in the CoLaus|PsyCoLaus cohort. Further research is needed to confirm whether socioeconomic disadvantage is a stronger predictor of objective than subjective memory. Subjective cognitive complaints are a criterion for the diagnosis of mild cognitive impairment (Petersen, 2004), but the inclusion of this criterion has been questioned as subjective cognitive complaints do not consistently predict objective cognitive performance (Topiwala et al., 2021).

Associations between social mobility trajectories and performance level followed a dose-response pattern: individuals who experienced a stable-low trajectory performed worse than those who experienced a stable-high trajectory and those who experienced upward social mobility. These findings corroborate previous research on predictors of epigenetic age (Fiorito et al., 2017), as well as cognitive performance (Luo & Waite, 2005; Staff et al., 2018; Turrell et al., 2002), and suggest some degree of reversibility of the effects of disadvantaged socioeconomic conditions in childhood. The observed differences could be brought about by social selection, with superior cognitive ability driving upward social mobility; although previous research found this association held even when taking into account early-life cognitive ability (Staff et al., 2018). The present study cannot identify the genetic and environmental contributions to the observed social mobility effects, but research indicates that both make a contribution (Belsky et al., 2018).

Just one known previous study examined associations between social mobility and memory decline, and found no association (Staff et al., 2018). The present study corroborates and extends this finding across different cognitive domains, and in two independent cohorts of older adults. There was an association between education level and greater decline in inhibitory control (in CoLaus|PsyCoLaus), and global impairment over 6 years. However, unlike findings for the level of cognitive performance, associations were not apparent across socioeconomic indicators or cognitive domains in either cohort. A number of studies have found little or no impact of education level, occupational position, or income on the rate of the cognitive decline (Lövdén et al., 2020), but some have reported positive or negative effects (Aartsen et al., 2019; Cadar et al., 2017; Lyu & Burr, 2016; Steptoe & Zaninotto, 2020). Null findings in the present study could be due to inadequate statistical power to detect significant effects, a limited follow-up period, and/or the inability to measure non-linear as well as linear trajectories of cognitive decline. A multi-cohort study using SHARE data ( $N = 24,066$ ) from multiple time points over 12 years, found



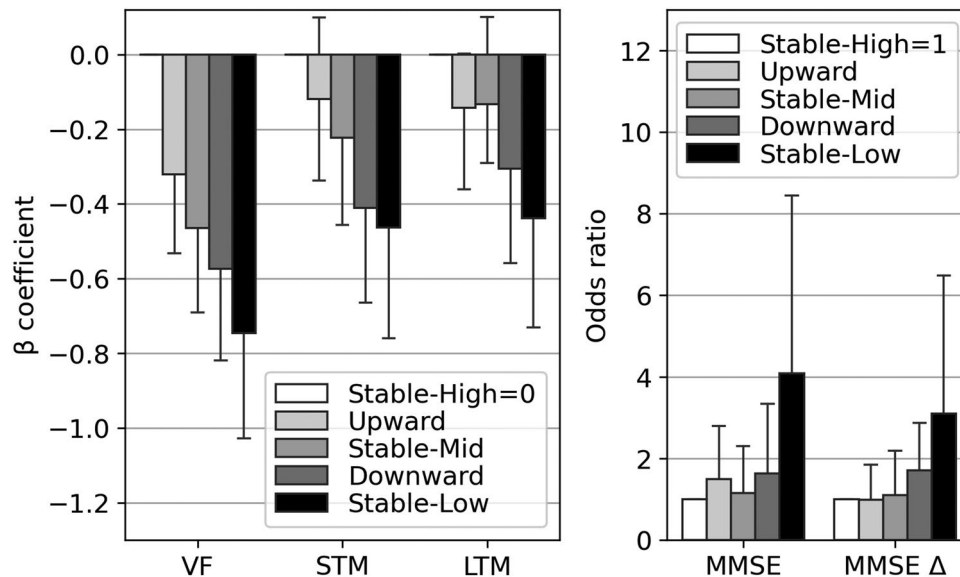
**Figure 1.** Associations between life-course socioeconomic disadvantage and the level of cognitive performance (top panel) as well as change in cognitive performance ( $\Delta$ , bottom panel) in the CoLaus|PsyCoLaus and VLV cohorts. Note. Linear regression results ( $\beta$ s) are shown for continuous cognitive variables, logistic regression results (ORs) are shown for categorical cognitive variables. Darker colours (ORs) represent stronger positive associations between socioeconomic disadvantage and global cognitive impairment/cognitive complaints. Darker colours ( $\beta$ s) represent stronger negative associations between socioeconomic disadvantage and cognitive performance. Asterisk indicates significant association after correction for multiple tests. Models adjusted for age, age squared, and sex.

**Table 2.** Associations between social mobility and the level of as well as change in performance in the CoLaus and VLV cohorts.

	CoLaus PsyCoLaus		VLV	
	Performance level, B/OR (95% CI)	Change in performance, B/OR (95% CI)	Performance level, B/OR (95% CI)	Change in performance, B/OR (95% CI)
Processing speed <sup>a</sup>	-0.37 (-0.75, 0.01)	-0.16 (-0.43, 0.12)	-0.26* (-0.48, -0.05)	-0.13 (-0.41, 0.16)
Verbal fluency	-1.05* (-1.40, -0.70)	-0.38 (-0.71, -0.05)	0.38* (-0.68, -0.09)	-
Cognitive flexibility <sup>b</sup>	0.13 (-0.25, 0.51)	-0.15 (-0.50, 0.19)	-0.24 (-0.60, 0.13)	-0.01 (-0.48, 0.47)
Inhibitory control	-0.67* (-1.01, -0.33)	-0.32 (-0.69, 0.04)	-	-
Short-term Memory	-0.80* (-1.15, -0.46)	-0.56 (-0.96, -0.16)	-0.30 (-0.61, 0.02)	-
Long-term Memory	-0.62* (-0.96, -0.28)	-0.30 (-0.71, 0.11)	-0.20 (-0.51, 0.12)	-
Cognitive complaints <sup>c</sup>	0.83 (0.32, 2.18)	0.98 (0.32, 3.00)	0.13 (-0.10, 0.35)	0.02 (-0.21, 0.26)
Global impairment <sup>d</sup>	1.76 (0.81, 3.80)	2.94* (1.18, 7.31)	2.81* (1.49, 5.27)	2.69* (1.40, 5.17)

Note: models adjusted for age, age squared, and sex; \*statistically significant after correction for multiple tests.

<sup>a</sup>performance on the Stroop color and word conditions (CoLaus|PsyCoLaus); Trail Making Test A (VLV), <sup>b</sup> performance on the verbal fluency switching condition (CoLaus|PsyCoLaus); Trail Making Test B/A (VLV), <sup>c</sup> Assessed using the Cognitive Complaints Questionnaire (CCQ) (CoLaus|PsyCoLaus); single item (0 – 3) (VLV), <sup>d</sup> Assessed using the Clinical Dementia Rating (scores  $\geq 0.5$  indicating impairment, CoLaus|PsyCoLaus) and the Mini State Mental Exam (scores  $< 27$  indicating impairment, VLV).



**Figure 2.** Associations between social mobility trajectories and cognitive performance in the pooled analysis. Note. Models adjusted for age, age squared, sex, and cohort. Error bars are 95% confidence intervals. VF = verbal fluency, STM = short-term memory, LTM = long-term memory, MMSE = Mini Mental State Examination. The stable-high socioeconomic trajectory was the reference group.

that socioeconomic advantage was associated with a greater decline in verbal fluency (Aartsen et al., 2019). This finding is in line with the idea that socioeconomic advantage may protect against age-related cognitive decline up to a certain point in life, but there comes a time when socioeconomic advantage can no longer compensate for age-related neuronal loss, and there is an acceleration or 'catch up' in cognitive decline. As in many other studies in this field, this study used data from a developed country, which invests in public education, and has a universal health insurance system. Although socioeconomic inequalities in health are evident in developed countries, including Switzerland (Mackenbach et al., 2008; Guessous et al., 2012), social mobility may be more strongly linked to cognitive outcomes, including cognitive decline, in countries with greater inequalities between lower and higher socioeconomic groups. In addition, more proximal experiences in older adulthood may be more strongly related to cognitive decline (e.g. Ihle et al., 2018; 2020). Further research is needed to examine the conditions under which socioeconomic disadvantage, including social mobility are associated with cognitive decline, using data from multiple time points, over a longer time frame, and in both developed and developing countries.

Differential access to appropriate healthcare, workplace conditions and cognitive demands (Then et al., 2014), exposure to psychosocial stressors (Chen & Miller, 2013), exposure to environmental pollution (Evans & Kantrowitz, 2002), and gene-environment interaction (Ryan et al., 2011) likely contribute to socioeconomic differences in cognitive health and decline. The neurobiological pathways underlying the effects of life-course socioeconomic disadvantage on cognitive performance remain unclear. Existing studies indicate that socioeconomic disadvantage is associated with aberrant structure in brain regions involved in memory, executive functions, language, and emotion regulation (Farah, 2017). However, research has primarily focused on earlier stages of the lifespan (Hedman et al., 2012), and has not simultaneously assessed cognitive performance. Further research should examine whether the social mobility effects seen in the present study are explained by differences in brain structure, including differences in white matter, which play an important role in cognitive development and decline (Madden et al., 2012).

### Strengths and limitations

Strengths of this study are the assessment of life-course socioeconomic disadvantage, the assessment of cognitive performance across multiple cognitive domains (in terms of level and change), and the consideration of key covariates, including health behaviors and depressive symptoms. However, cognitive decline was assessed using data from two time points spaced 6 years apart, and longitudinal data was not available for all of the cognitive domains in VLV. Future research should further examine associations between social mobility and cognitive performance assessed across domains and at multiple time points. Systematic attrition did not eliminate entire population groups of interest in the current study. However, as in many longitudinal studies, some degree of sampling bias may have been present. Participants in the longitudinal analysis were younger, and a smaller proportion had comorbidities and MMSE scores <27 compared to those lost at follow-up. Individuals from lower socioeconomic groups in this sample may be healthier or more resilient than those who did not participate, which would lead to an underestimation of the results found. In addition, this study did not have information on early-life cognitive ability, which is an important predictor of cognitive decline (Ritchie et al., 2016); nor can the study distinguish between 'social selection', 'social causation', or 'common cause' explanations of the findings (Goldman, 2001).

### Conclusion

This study found that individuals who experienced socioeconomic disadvantage across the life course had a poorer level of cognitive performance than those who experienced upward social mobility. However, there were no consistent associations with cognitive decline. Further research is needed to examine the neurobiological mechanisms underlying the observed findings, as well as the conditions under which socioeconomic disadvantages are associated with cognitive decline.

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## Author contributions

All authors contributed to the conception and design of the study. Stephanie Schrepft, Olga Trofimova, and Morgane Künzi prepared the data and performed the statistical analyses. Stephanie Schrepft wrote the paper. All authors contributed to the revision of the paper. Silvia Stringhini, Bogdan Draganski, and Matthias Kliegel provided supervision.

## Disclosure statement

The authors report there are no competing interests to declare.

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## Data availability statement

The data that support the findings of this study are available on request from the corresponding author, [SGS]. The ethics protocols under which the data were collected do not permit public data deposition.

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