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Research article

Non-economic social deprivation and cognitive functioning later in life: Results from the DELCODE study

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Abstract

Background: Low socioeconomic status is associated with a higher risk for a number of health conditions, including cognitive impairment.

Objective: While the association with economic indicators has been well researched, aim of this paper was to investigate specifically the association between non-economic social deprivation and cognitive functioning later in life.

Methods: Participants without objective cognitive impairment at baseline (n = 91 controls, n = 106 with subjective cognitive decline) of the multicenter DZNE-Longitudinal Cognitive Impairment and Dementia Study (DELCODE) filled out a posthoc survey on social deprivation. Factor analysis identified four non-economic domains of social deprivation (Residential area conditions, Accessibility, Neighborhood support, Household distress). Cognition was assessed via the CERAD neuropsychological battery. Analyses were conducted using linear regression models as well as maximum-likelihood mixed-effects models adjusted for age, gender, years of education, marital status, depression, BMI, heart disease,

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hypercholesterolemia, hypertension, and diabetes.
Results: At the time of the survey, cognitive functioning was significantly lower among participants with high deprivation ($b = -0.21$, $p = 0.037$). These participants also had a faster rate of cognitive decline ($b = -0.07$, $p = 0.006$). Analyses of the deprivation sub-scores revealed statistically significant effects only for Accessibility ($b = -0.31$, $p = 0.001$; rate of cognitive decline $b = -0.07$, $p = 0.004$).
Conclusions: Our findings suggest that non-economic social deprivation, especially in terms of access to a grocery store, pharmacy, postal office, and bus stop, might be relevant for maintaining cognitive functioning in old age. Further research should explore potential mechanisms of how these environmental conditions affect brain aging and neurodegenerative processes.

Keywords
Alzheimer's disease, cognitive decline, disparities, mild cognitive impairment, social deprivation, socioeconomic, subjective cognitive impairment

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Introduction

It is well-known that individuals with lower socioeconomic status tend to have poorer health (e.g.,[1–4]). Until today, it is not exactly clear why this is the case. Socioeconomic status is a concept that is usually composed of education, occupational attainment, and income. Each of these components reflects a person's status to access or own resources in a society. Hence, there is the predominant notion that the availability of financial resources influences whether a person has a better or poorer health.[5,6] Indeed, an increasing number of studies points out that financial strain is associated with poorer health.[7] However, among individuals with low socioeconomic status, there are factors on the individual, family, and neighborhood level that can influence systemic inflammation, cellular processes, genomic, and other pathways and in this way lead to poorer health.[8] Accordingly, researchers started expanding the concept "socioeconomic status" to the concept "social deprivation". Social deprivation describes a state of disadvantage relative to the wider society and includes—besides education and occupation—multidimensional aspects.[9] Aspects differ greatly by author and are, for example, unemployment, car/home ownership, overcrowding,[10] or any other social determinant (i.e., conditions beyond medical, demographic, and individual lifestyle factors, which may influence people's health[11]). A variety of research studies demonstrated that social deprivation is associated with higher mortality of all causes[12] as well as a higher prevalence of musculoskeletal pain,[13] diabetes type 2,[14] chronic kidney disease,[15] psychosis,[16] and accelerated aging,[17] among others.

Regarding cognitive decline and dementia, the association between low socioeconomic status and a higher risk for developing dementia is well established.[18,19] Studies on social deprivation have used indicators on financial resources and confirmed associations between higher social deprivation and worse cognitive functioning in old age[20]; even more so if the index included information on the ability to afford a holiday, replacing worn-out clothing, or missing a necessary doctor appointments to save on expenses.[21] One explanation for this association is that economic disadvantages accumulate disease burden,[22] which may then lead to a higher dementia risk. However, this pathway might not be the only one, as studies demonstrated that such effects tend to remain significant after adjusting for health conditions.[23] The idea that something else influences dementia risk is supported by papers that show associations between other than economic aspects and cognitive health in old age. For instance, data from the 10/66 study demonstrated that living far from daily life amenities is associated with a higher risk for dementia.[24] Further, conditions of the neighborhood such as green spaces, street disrepair index, safety, and cleanliness as well as higher land-use mix were associated with cognitive functioning in older age.[25,26] The extent of air pollution also appears to be relevant.[27] Two recent studies reported that problems in the neighborhood (e.g., crime, low sense of collaboration between inhabitants) are associated with lower cognitive functioning in old age.[28,29] In fact, publications on the possible effects of the actual "social" aspects of social deprivation in terms of inter-person relationships and interactions (e.g., neighborhood support) are rare. As deprivation research has its origins in poverty research, economic indicators such as possessions and the ability to afford things have dominated the concept of social deprivation[30] and non-economic aspects have not received much attention. Accordingly, there is also a lack of a theoretical framework or conceptual approach of how non-economic deprivation influences health. In this paper, we chose a data-driven approach to explore non-economic aspects, which could later lead to the development of a respective theory. Moreover, previous studies that included non-economic aspects looked at each aspect individually so that knowledge

on broader non-economic categories is lacking. Evidence as this can be valuable given that the United Nations declared the elimination of characteristics in a community, that convey risks for health, a priority in the Sustainable Development Goals.[31] A solid knowledge base of characteristics of social deprivation that influence the risk for cognitive impairment in old age can guide public policy and aid the development of prevention guidelines.

Objective

The aim of this study was to investigate how individual-level non-economic social deprivation is associated with cognitive functioning in later life. Specifically, we tested the hypothesis that individuals with higher deprivation are more likely to have lower cognitive functioning than individuals with lower deprivation.

Methods

Study design

The multicenter *DZNE-Longitudinal Cognitive Impairment and Dementia Study* (DELCODE, details published elsewhere[32]) included individuals with mild cognitive impairment (MCI), subjective cognitive decline (SCD), mild dementia of the Alzheimer's type (DAT), as well as control subjects without subjective or objective cognitive impairment. Aims of DELCODE were to develop an understanding of SCD and MCI in the context of AD, establish prediction models, and investigate the effects of risk and protective factors on cognitive decline. Recruitment started in 2014 and took place through referrals, including self-referrals, to ten university-based memory centers and, for the control group, via standardized public advertisement. Inclusion criteria were age ≥ 60 years, fluent German language skills, and capacity to provide informed consent. Exclusion criteria were conditions clearly interfering with participation in the study or the study procedures (e.g., severe sensory impairment) as well as a current major depressive episode, major psychiatric disorders, neurodegenerative disorder other than AD or vascular dementia, a history of stroke with residual clinical symptoms, history of malignant disease, severe or unstable medical condition, severe clinical abnormalities in vitamin B12, and chronic use of psychoactive compounds or anti-dementia agents. Participants underwent a medical examination and cognitive testing and were invited to come to the study center for annual follow-ups. All participants signed an informed consent. The study was approved by the ethical committees of all participating sites coordinated by the ethical committee of the medical faculty of the University of Bonn (number 117/13).

A total of 400 individuals with SCD, 200 with MCI patients, 100 AD, 200 control subjects, and 100 first-degree relatives of DAT patients were recruited. For this analysis, we excluded participants who were diagnosed with brain tumor, Huntington's, Parkinson's, schizophrenia, multiple sclerosis, epilepsy, hydrocephalus, meningitis, encephalitis, or sleeping problems during either of their visits ($n = 89$). Moreover, as the questionnaire on social deprivation took place in 2020 during follow-ups, only $n = 333$ participants filled out all the necessary questions on social deprivation. Of those, $n = 126$ had to be excluded because cognitive data for the respective assessment wave was incomplete. Of the remaining participants only $n = 2$ had DAT and $n = 8$ MCI at baseline so that these groups were excluded as well. The final sample for analysis comprised $n = 197$ participants ($n = 91$ controls, $n = 106$ with SCD). On inclusion into the DELCODE study, SCD was defined with (i) concerns about subjectively perceived cognitive decline and (ii) cognitive performance in the CERAD neuropsychological battery above 1.5 standard deviations (SD) of the age, sex, and education-adjusted norms. Participants kept their initial diagnostic group assignment (SCD, Controls) irrespective of the cognitive outcomes during follow up. SCD patients were more likely to develop incident MCI during follow-up than controls.[33]

Social deprivation

In 2020, a post-hoc questionnaire on social deprivation with questions that specifically focus on non-economic aspects of social deprivation was added to the follow-up visits. For 21.8% ($n = 43$) of the participants included in the analysis, it was their 3rd, for 16.8% ($n = 33$) their 4th, for 28.4% ($n = 56$) their 5th, for 25.9% ($n = 51$) their 6th, and for 7.1% ($n = 14$) their 7th assessment. Overall $n = 410$ DELCODE participants had filled out the questionnaire, however, not everyone completed all of the questions.

To derive a deprivation score, in the first step, we excluded questions that had 10% or more missings ($n = 23$ questions) from analysis. In a second step, we reversed the coding of 24 questions so that for all variables higher scores represent being better off (i.e., less deprivation). In a third step, we estimated factors of social deprivation because Spearman's rank correlation indicated a great variance in the strength of the correlation between the questions. Minimum average partial correlation according to Velicer indicated three principal components and the screeplot suggested four factors. Principal component analysis with orthogonal rotation (because skewness and kurtosis tests indicated non-normal distribution of most questions) demonstrated similar BIC values for the three and four factor models (3 factors $BIC = 2290$, 4 factors $BIC = 2299$) and the lowest AIC for the four factor model (3 factors $AIC = 1856$, 4 factors $AIC = 1727$). Hence, we chose the four factor model. Details of the model are shown in Supplemental Table 1.

As the factors did not yet have a good internal consistency, we then ran confirmatory factor analysis using asymptotic distribution free (ADF) structural equation modeling with an ADF weighting matrix, for each of the four factors separately (as the complete model did not converge). If the factor did not have a CFI > 0.8 and/or a TLI >0.80, we removed the question with the lowest coefficient. This was repeated until the factor met these criteria (excluded questions shown in Supplemental Table 2). Using those improved factors, we ran a complete confirmatory factor analysis again. To achieve a better fit, questions with a coefficient <0.3 were removed (see Supplemental Table 2). The final model comprised the four factors *Residential area* (Factor 1: air pollution, trouble/problems, scared at night, risky to walk), *Accessibility* (Factor 2: next pharmacy, next bus stop, next postal office, next grocery store), *Neighborhood support* (Factor 3: neighbors visit each other, do favors, ask advice, help each other), and *Household distress* (Factor 4: high demands, being criticized, feel threatened, for details see Supplemental Table 2) and had a root mean squared error of approximation model (RMSEA) of 0.052, a Comparative fit index (CFI) of 0.897, and a Tucker-Lewis index (TLI) of 0.875. A sum score of the variables of each factor was calculated. The total deprivation score is the sum score of the standardized factor scores. For purpose of analysis, the scores are categorized using the median so that the 50% with the lowest values (indicating being worse off) were assigned to the "high deprivation" group and the 50% with the higher values (indicating being better off) were assigned to the "low deprivation" group.

To check reliability, we compared the scores of those participants who completed the questionnaire a second time in the subsequent follow-up. Kappa between the categorized scores was $K = 1.000$, $p < 0.001$ with an agreement of 100%.

Cognitive functioning

Cognitive performance was assessed via the CERAD neuropsychological battery. A cognitive score was calculated according to Papp et al. (2017)[34] to achieve a good indication on amyloid-related decline in semantic memory in early AD. In a first step, z-scores from the baseline performance of all cognitively unimpaired DELCODE participants in five cognitive measures were obtained: the Mini-Mental State Exam (MMSE), the Free and Cued Selective Reminding Test (FCSRT) free and total recall, the Wechsler Memory Scale—Fourth Edition (WMS-IV) Logical Memory Story B delayed recall, the Symbol-Digit Modalities Test (SDMT), and the sum of two category fluency tasks (Animal and Food). In a second step, the z-standardized performance of all participants in each of the cognitive measures and at all assessment points were estimated. Finally, the cognitive composite score was derived by taking the average of the standardized z-scores of the five cognitive measures. In addition, a mean annual rate of change was calculated by, first, calculating the difference in the first and last cognitive composite score for each participants, and then dividing it by the time (in years) from their first to their last cognitive assessment.

Confounding variables

Gender was used as indicated by the participant. Age was calculated as the difference between assessment date and birthdate. For education, we used years of education. Marital status was categorized into those being alone (single, divorced, or widowed) and being with somebody (married or with a partner). Body mass index is the body weight in kilograms divided by the square of the height in meters. Having hypertension, diabetes, depression, heart disease, and/or hypercholesterolemia was determined via diagnostic codes of the participants.

Statistical analyses

Data analysis was conducted using Stata 16. We used a level of significance of $p < 0.001$; for comparison of the four sub-scores, a Bonferroni-corrected level of significance of $p < 0.0125$ was used.

The association between social deprivation and participant characteristics was estimated using chi-square tests and Kruskal-Wallis tests. The association between social deprivation and cognitive functioning was estimated for the assessment, in which the participant first completed the social deprivation questionnaire. Linear regression analyses were adjusted for age, gender, years of education (box-cox transformed), marital status, depression, BMI, heart disease, hypercholesterolemia, hypertension, and diabetes.

To estimate associations between social deprivation and change in cognitive functioning, we used maximum-likelihood mixed-effects models with random intercepts for each participant (autoregressive residuals, unstructured covariance). As social deprivation was assessed via a posthoc questionnaire, cognitive change was modelled for the three assessments before the questionnaire as well as the assessment, in which the questionnaire was completed and for which had a sufficient number of participants was available. Models were centered at the time of the social deprivation questionnaire and had fixed effects for social deprivation, follow-up, the square of follow-up, the interaction of social deprivation and follow-up, age, gender, years of education (box-cox transformed), marital status, depression, BMI, heart disease, hypercholesterolemia, hypertension, and diabetes.

Table 1. Sample characteristics.

Characteristic		Total (n = 197) % (n)	High social deprivation (n = 92) % (n)	Low social deprivation (n = 105) % (n)	χ^2 (p)
Gender	Female	52.3 (103)	54.4 (50)	50.5 (53)	0.295 (0.587)
	Male	47.7 (94)	45.7 (42)	49.5 (52)	
Marital status	Single/divorced	34.0 (67)	38.0 (35)	30.5 (32)	1.251 (0.263)
	Married/partner	65.9 (130)	61.9 (57)	69.5 (73)	
Hypertension	No	51.3 (101)	44.6 (41)	57.1 (60)	3.105 (0.078)
	Yes	48.7 (96)	55.4 (51)	42.9 (45)	
Hypercholesterolemia	No	67.5 (133)	65.2 (60)	69.5 (73)	0.415 (0.520)
	Yes	32.5 (64)	34.8 (32)	30.5 (32)	
Diabetes	No	92.4 (182)	89.1 (82)	95.2 (100)	2.600 (0.107)
	Yes	7.6 (15)	10.9 (10)	4.8 (5)	
Heart disease	No	81.2 (160)	84.8 (78)	78.1 (82)	1.438 (0.231)
	Yes	18.8 (37)	15.2 (14)	21.9 (23)	
Depression	No	93.4 (184)	91.3 (84)	95.2 (100)	1.231 (0.267)
	Yes	6.6 (13)	8.7 (8)	4.8 (5)	
		M (SD)	**M (SD)**	**M (SD)**	**χ^2 (p)**
BMI		25.3 (3.6)	25.1 (3.5)	25.6 (3.6)	0.446 (0.504)
Years of education		14.9 (2.9)	14.9 (2.9)	14.9 (2.9)	0.014 (0.906)
Age		69.5 (5.6)	70.7 (5.9)	68.5 (4.9)	7.156 (0.008)

BMI: body mass index; MCI: mild cognitive impairment; n: number of participants; p: level of significance; SCI: subjective cognitive decline.

Results

Participant characteristics are shown in Table 1. Participants with high social deprivation were significantly more likely to be older. There were no other statistically significant differences.

Among those with high deprivation, 64.1% ($n = 59$) were participants with SCD. This number was smaller among those low deprivation (44.8%, $n = 47$; $\chi^2 = 7.401$, $p = 0.007$). Mean cognitive functioning at the time of the social deprivation questionnaire was 0.09 ($SD = 0.79$). It was slightly lower for those with SCD ($M = -0.12$, $SD = 0.87$) than for the controls ($M = 0.34$, $SD = 0.61$).

Participants with high deprivation had a statistically significantly lower cognitive functioning ($M = -0.09$) than participants with low deprivation ($M = 0.24$, see Table 2). Concerning the social deprivation sub-scores, higher deprivation in Accessibility (Factor 2) was statistically significantly associated with lower cognitive functioning (see Table 2). There were no significant differences for the other social deprivation sub-scores. Confounder-adjusted regression analysis confirmed a significantly lower cognitive functioning for participants with high social deprivation (total score, see Figure 1) as well as high deprivation in *Accessibility* (Factor 2; see Table 2).

Longitudinal cognitive data was available for 78.7% ($n = 155$) participants for one year, 88.8% ($n = 175$) two years, 95.9% (n = 189) three years, 74.6% ($n = 147$) four years, 59.9% ($n = 118$) five years, 32.9% ($n = 65$) six years, and 7.1% ($n = 14$) seven years. The overall mean annual rate of change was −0.00 ($SD = 0.13$). It was slightly lower for those with SCD ($M = -0.02$, $SD = 0.14$) than for the controls ($M = 0.02$, $SD = 0.11$). Participants with high deprivation had, on average, a larger mean annual rate of cognitive functioning ($M = -0.34$, $SD = 0.15$) than participants with low deprivation ($M = 0.03$, $SD = 0.10$, $\chi^2 = 11.451$, $p < 0.001$). Concerning the social deprivation sub-scores, we observed the same pattern for *Accessibility* (Factor 2, high $M = -0.02$, $SD = 0.15$; low $M = 0.03$, $SD = 0.09$), but it reached only a level of significance of $p = 0.020$ ($\chi^2 = 5.409$). There were no significant differences for the other social deprivation sub-scores (Residential area (Factor 1) $\chi^2 = 0.005$, $p = 0.943$; Neighborhood support (Factor 3) $\chi^2 = 1.293$, $p = 0.256$; Household distress (Factor 4) $\chi^2 = 0.507$, $p = 0.477$). To validate these observations, we ran confounder-adjusted mixed-models analysis. Results indicate a significantly faster cognitive decline for participants with high deprivation (total score, see Figure 2) as well as high deprivation in *Accessibility* (Factor 2), and again not any other of the sub-scores (see Table 3). Adjusting this analysis additionally for being SCD/ control participant did not alter the findings (total score*follow-up $b = -0.07$, CI95% −0.11 – −0.02, $p = 0.007$; *Accessibility**follow-up $b = -0.07$, CI95% −0.12 – −0.02, $p = 0.004$).

Discussion

The aim of this paper was to investigate the association between non-economic social deprivation and cognitive

Table 2. Association between social deprivation and cognitive functioning.

		Cognitive functioning					
Social deprivation		Means M (SD)	χ^2 (p)	Univariate regression b (CI95%)	p	Adjusted regression§ b (CI95%)	p
Total score	High	−0.09 (0.89)	6.937 (0.008)	−0.34 (−0.56; −0.12)	0.003	−0.21 (−0.40; −0.01)	0.037
	Low	0.24 (0.66)		REF		REF	
Residential area (Factor 1)	High	0.11 (0.73)	0.002 (0.967)	0.04 (−0.19; 0.27)	0.715	0.05 (−0.15; 0.245)	0.642
	Low	0.06 (0.89)		REF		REF	
Accessibility (Factor 2)	High	−0.13 (0.88)	17.590 (<0.001)	−0.51 (−0.72; −0.29)	<0.001	−0.31 (−0.51; 0.12)	0.001
	Low	0.37 (0.55)		REF		REF	
Neighborhood support (Factor 3)	High	0.06 (0.83)	0.065 (0.799)	−0.06 (−0.29; 0.17)	0.585	0.00 (−0.19; 0.19)	0.996
	Low	0.13 (0.74)		REF		REF	
Household distress (Factor 4)	High	0.06 (0.79)	0.229 (0.632)	−0.07 (−0.29; 0.16)	0.545	0.06 (−0.14; 0.25)	0.572
	Low	0.13 (0.80)		REF		REF	

§adjusted for age, gender, education, marital status, depression, body mass index (BMI), heart disease, hypercholesterolemia, hypertension, and diabetes; b: coefficient; CI95%: 95% confidence interval; p: level of significance; REF: reference category.

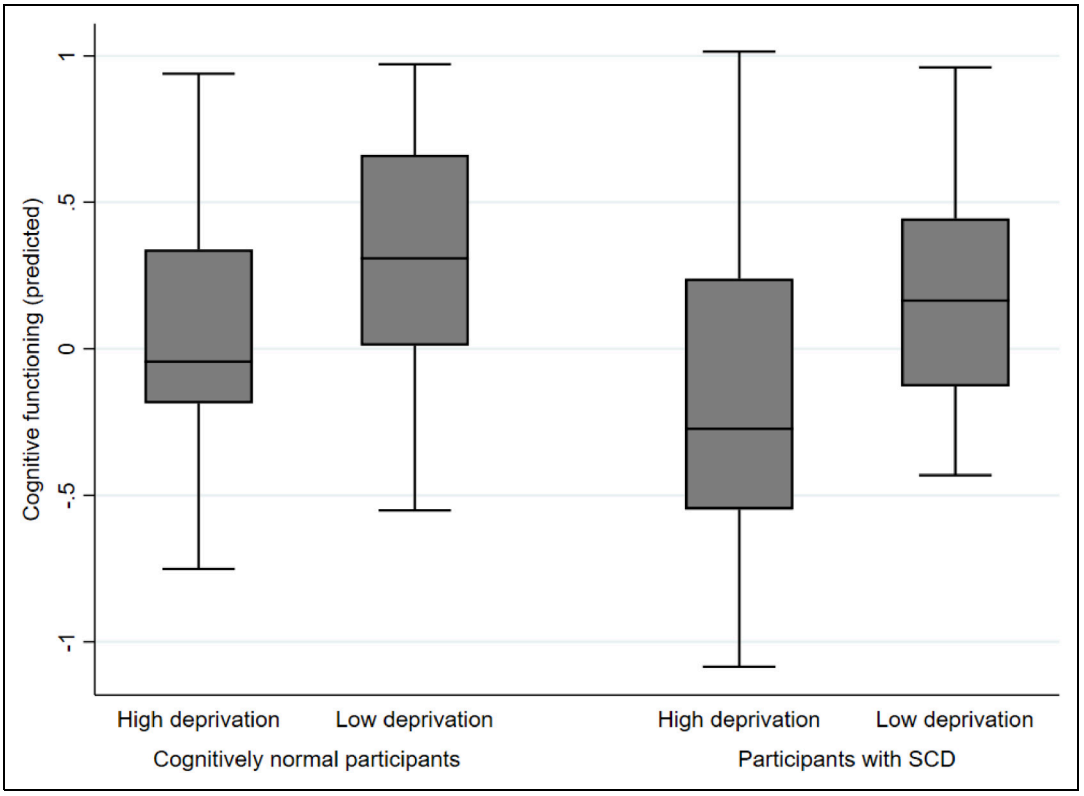

Figure 1. Cross-sectional association between social deprivation and cognitive functioning, estimated via linear regression analysis adjusted for age, gender, education, marital status, depression, BMI, heart disease, hypercholesterolemia, hypertension, and diabetes. SCD: subjective cognitive decline.

functioning later in life. Analyses of cognitively normal individuals and people with SCD indicate that participants classified with high levels of non-economic social deprivation had a lower cognitive functioning (about 0.2 of a standard deviation) as well as a faster rate of cognitive decline (about 0.2 of a standard deviation over three follow-

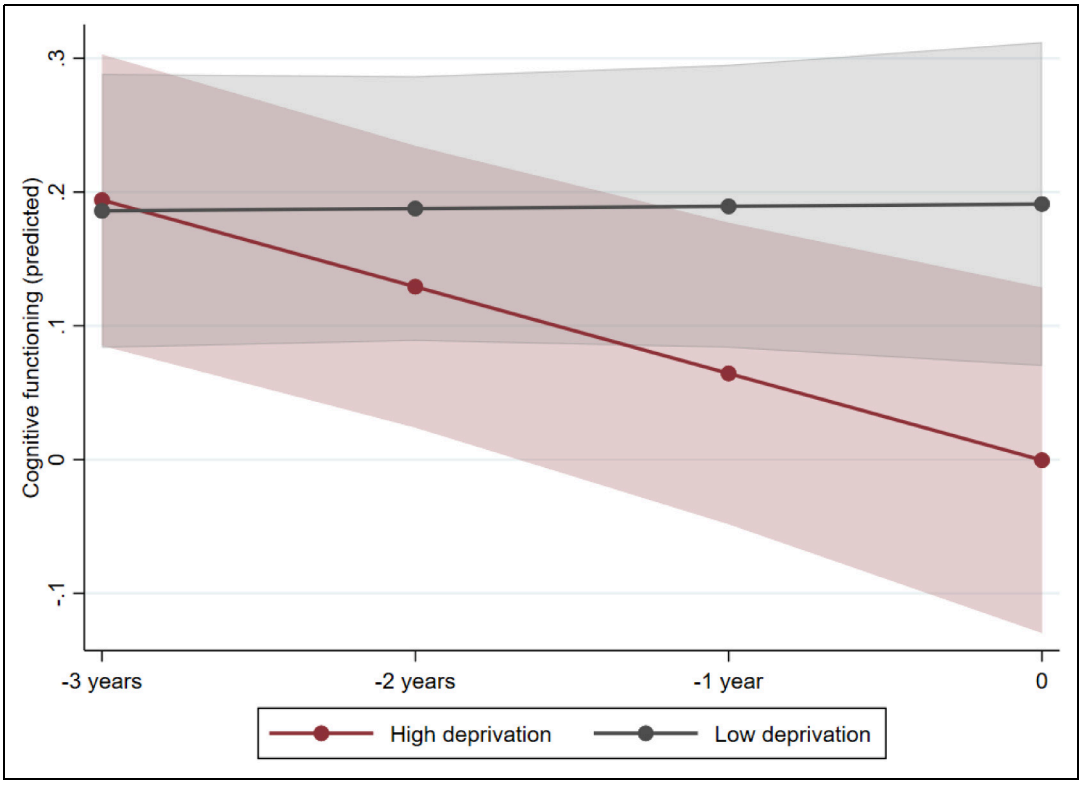

Figure 2. Modelled rate of cognitive functioning prior to completing the social deprivation questionnaire, estimated via mixed-effect models adjusted for age, gender, education, marital status, depression, BMI, heart disease, hypercholesterolemia, hypertension, and diabetes.

Table 3. Estimates from mixed-effect models on the association of social deprivation and cognitive functioning over the study period, adjusted for age, gender, education, marital status, depression, body mass index (BMI), heart disease, hypercholesterolemia, hypertension, and diabetes.

Deprivation		b	CI95%	p
Total score	High §	6.46	1.84; 11.08	0.006
*FU	High §	−0.07	−0.11; −0.02	0.006
Residential area (Factor 1)	High	−0.82	−5.63; 3.99	0.737
*FU	High §	0.01	−0.04; 0.06	0.719
Accessibility (Factor 2)	High §	6.68	2.03; 11.33	0.005
*FU	High §	−0.07	−0.12; −0.02	0.004
Neighborhood support (Factor 3)	High §	−0.08	−4.89; 4.73	0.973
*FU	High §	0.00	−0.05; 0.05	0.978
Household distress (Factor 4)	High §	3.35	−1.35; 8.04	0.163
*FU	High §	−0.03	−0.08; 0.01	0.174

§reference low deprivation; b, coefficient; CI95%: 95% confidence interval; FU: follow-up; p: level of significance; REF: reference category; SocD: social deprivation.

ups). Analyses of the sub-scores revealed only statistically significant findings for Accessibility (i.e., access to a grocery store, pharmacy, postal office, and bus stop). It appears that difficulties in accessing daily life amenities drive the effect of the total social deprivation score. However, given that the effect size is much smaller than of the total score (see Tables 2 and 3), it is more likely that the total score reflects cumulative disadvantage.

Our findings confirm previous observations on associations between high social deprivation and poorer cognitive health in old age (e.g.,[35]). Importantly, our findings emphasize that this association persists when including only non-economic indicators. This is relevant as the majority of social deprivation indices include income, employment status, wealth, and/or financial status among others.[36] Previous studies have demonstrated that living in socially

deprived neighborhoods is associated with worse cognitive health[37,38] While it can be argued that this is still an aspect of economic affluence, infrastructure of the neighborhood is not. Previous studies have shown that living close to daily life amenities[24] and accessible public transport is associated with lower dementia risk[39] and that proximity to public transit and community resources[40] as well as a greater number of public transportation stops, supermarkets, civic organizations, community centers, recreational facilities, and library accessibility is associated with better cognitive functioning in old age.[26] This underlines the importance of Accessibility for cognitive health, which was significant in our analyses. However, not all facilities may be relevant (e.g., health facilities) as some studies with non-significant effects suggest.[26] Before jumping to the conclusion that urban environments with high densities of bus stops and grocery stores are beneficial for maintaining cognitive functioning later in life, it is important to mention that traffic-bearing road proximity and low levels of neighborhood greenness (i.e., park areas, tree canopies, open grassy areas) are associated with an increased dementia risk, as meta-analyses have demonstrated[41,42] . Hence, urban environments may not necessarily be superior to rural areas. With older age, the prevalence of several health conditions (e.g., cardiovascular diseases, chronic respiratory diseases, musculoskeletal diseases) increases,[43] making it more difficult for a person to manage daily life. Living in proximity to daily life amenities and public transportation could help older people to remain independent despite physical limitations. It could also help them to continue participating in social and leisure activities, which is known to come with a lower risk for developing dementia.[44] Hence, mediating pathways through lifestyle behavior are possible.

At this point, it still remains unclear whether the relationship between non-economic aspects of social deprivation and cognitive functioning is causal and what the neurobiological mechanisms could be. Cumulative social disadvantages could be triggering emotional distress, which, if chronic, can cause neuroendocrine/immune imbalances[45] and possibly even accelerate brain aging.[46] Then again, individuals with higher social deprivation tend to experience more problems with self-care, usual activities, anxiety, and depression,[47] which could also affect their vulnerability to chronic health conditions and cognitive decline. Further research is necessary to investigate specific pathways.

Our study is not without limitations. First of all, the sample did not include dementia patients. Hence, it is not possible to draw any conclusions regarding dementia risk yet. Accordingly, our sample misses on variance at the lower end of cognitive functioning so that the results may underestimate the true effect. Second, our sample may not reflect the entire population and we recommend the repetition of the analysis in a population-representative sample. Third, the analysis of cognitive change is retrospective. Fourth, we did not complete information on all of the participants risk factors such as income, vision loss, intellectual activities etc. (see[48]) so that we cannot exclude the possibility that some of them may influence the observed association. Fifth, using an Exploratory SEM (ESEM) model to confirm the factor structure and then predict cognitive functioning may have led to different results. Sixth, there is always the risk of reverse causality. Individuals with a predisposition for faster cognitive decline may live in more remote areas.

In conclusion, our results indicate that non-economic social deprivation may be relevant for cognitive health in old age. In particular, accessibility (e.g., to groceries stories, pharmacies, postal offices, and bus stops) seems to play a role. This finding supports the idea that aspects not related to wealth but, in this case, infrastructure may affect cognitive functioning later in life. More research is necessary to establish causal associations so that targets for preventative measures that protect cognition in old age can be identified.

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Ethical considerations

The general study protocol for DELCODE was approved by the ethical committees of the medical faculties of all participating sites: the ethical committees of Berlin (Charité, University Medicine), Bonn, Cologne, Göttingen, Magdeburg, Munich (Ludwig-Maximilians-University), Rostock, and Tübingen. The process was led and coordinated by the ethical committee of the medical faculty of the University of Bonn (registration number 117/13).

Consent to participate

All included subjects gave informed consent. The DELCODE study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable

Author contribution(s)

Francisca S. Rodriguez: Conceptualization; Formal analysis; Writing – original draft.
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Data availability statement

Data is available upon request at https://www.dzne.de/en/research/studies/clinical-studies/delcode.

Supplemental material

Supplemental material for this article is available online.

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