Social Isolation and Loneliness: Relationships With Cognitive Function During 4 Years of Follow-up in the English Longitudinal Study of Ageing

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Objective: This study aims to evaluate the impact of social isolation and loneliness, individually and simultaneously, on cognitive function in older adults during a 4-year period, using data from the English Longitudinal Study of Ageing, and to evaluate if these associations are moderated by educational level. **Methods:** Data on social isolation, loneliness, and cognitive function (verbal fluency, immediate recall, and delayed recall) were obtained at baseline. Follow-up measures on cognitive function were obtained 4 years later for 6034 participants (mean age at baseline = 65.6 years). Regression analyses were used to evaluate the association between baseline isolation, loneliness, and cognitive function at follow-up. Interactions between social isolation, loneliness, and educational level were also evaluated. **Results:** Baseline isolation was significantly associated with decreases in all cognitive function measures at follow-up ($\beta = -.05$ to $-.03$, $p < .001$), independently of baseline scores, whereas loneliness was associated with poorer immediate recall ($\beta = -.05$, $p < .001$) and delayed recall ($\beta = -.03$, $p = .02$). There was a significant interaction between educational level and both isolation ($p = .02$) and loneliness ($p = .01$) for delayed recall, such that isolation and loneliness were associated with poorer recall only among those with low levels of education. **Conclusions:** Loneliness and isolation are associated with poorer cognitive function among older adults. Interventions to foster social connections may be particularly beneficial for individuals with low levels of education. **Key words:** social isolation, loneliness, cognitive function, older adults, education, cognitive reserve.

AD = Alzheimer's disease; **CES-D** = Center for Epidemiologic Studies Depression scale; **CVD** = cardiovascular disease; **ELSA** = English Longitudinal Study of Ageing; **SES** = socioeconomic status.

INTRODUCTION

Dementia is an umbrella term encompassing conditions such as Alzheimer's disease (AD), vascular dementia, and dementia with Lewy bodies (1). The condition is characterized by increasing loss of memory, confusion, and personality changes, as well as problems with verbal or written expression, spatial orientation, and other everyday activities (2). More than 36 million individuals worldwide are believed to have dementia, with the numbers expected to nearly double by 2030 and to rise as high as 115.4 million by 2050 (3). Dementia is more common in older age, and the risk doubles every 5 years after the age of 65 years (3). It has been estimated that delaying the onset of dementia by 5 years can reduce up to 30,000 deaths a year (4). This has led to an increasing interest in identifying modifiable factors that may help protect cognitive function in older age, and one factor that has received considerable attention is social relationships.

Studies have focused on objective measures of social isolation, as well as perceived isolation or loneliness. Social isolation is an objective, quantitative measure of network size, network diversity, and frequency of contact (5). Although several studies have evaluated the effect of isolation on cognitive decline and development of dementia, the results from these studies are mixed (6). This is, at least in part, attributable to the many ways in which this concept has been defined. The simplest measures include only marital status or living arrangements. Some studies report that marriage or cohabitation is protective against developing AD (7,8) and is associated with better cognitive function in older age (9), whereas others find no significant effects (10,11). Studies combining marital status with living arrangements have found that individuals who are single (never married) and living alone are at higher risk for impaired cognitive function or dementia than those who are married and living with others (12,13). Findings on the effects of network size, including frequency of contact with friends or family, are also mixed (8,14–16). Other studies consider social activities, such as visits to friends or relatives (16), and subjective evaluations of social engagement, such as whether individuals feel able to help family or friends (17). Higher levels of social activity and engagement are negatively associated with cognitive decline (18–22) and development of AD/dementia (23,24). More recently, there has been an interest in studying the effect of perceived isolation or loneliness on cognitive function. Loneliness is a subjective evaluation referring to the extent to which individuals are satisfied with their social contacts (5). In an experimental study, individuals who were told that they would end up alone in the future performed significantly worse on cognitive tests than individuals who were told that they would be surrounded by people who cared about them (25). Longitudinal studies have also found loneliness to be associated with decline in cognitive function (26).

Although it is clear that social isolation and loneliness are related, the association between the two variables is typically small to moderate (27). Changes to networks are common in older age and may occur through retirement, bereavement, children moving away, and so on. As individuals grow older, they may expect such changes to take place and hence be more prepared to deal with them; thus, these changes may not necessarily lead to feelings of loneliness (28). It has been suggested that isolation be studied in conjunction with loneliness to better understand how various aspects of social interactions affect health (28,29). Analysis from the Rush Memory and Aging Project found that participants who were lonely and those with limited participation in social activities were significantly more likely to develop AD. However, network size was not significantly associated with development of AD (16). Similarly, analysis of the PAQUID (Personnes Agées QUID) study in

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France found that satisfaction with contacts, but not marital status or network size, was associated with development of AD (30). Other studies reported that aspects of networks, but not satisfaction, are more closely associated with the incidence of AD/dementia (8,23). In a study combining objective and perceived isolation, Fratiglioni et al. (13) found that parents who were dissatisfied with the contact they had with their children nearly doubled their risk of incident dementia. Given the small number of studies examining isolation and loneliness together, the different ways in which isolation has been defined, and the inconclusive findings in this area, the present study aimed to evaluate the association between social isolation, loneliness, and cognitive function in older adults. On the basis of previous research indicating a weak association between isolation and loneliness, particularly in older adults (28,31), we hypothesized that both social isolation and loneliness would be independently predictive of poorer cognitive function over time. However, we made no specific predictions regarding the strength of the associations.

When studying cognition, consideration of educational level is particularly important, as education contributes to an individual's cognitive reserve. The concept of reserve refers to aspects of brain structure and function that can play a protective role against neuropathology, such that among individuals with greater reserve, the clinical manifestation of dementia is observable only at very severe levels of brain pathology (32). In addition to education and other socioeconomic status (SES) factors, social relations may also play a part in building up cognitive reserve through communication and interaction (13,33). Hence, it is reasonable to think that the effects of isolation and loneliness may be more pronounced in those with lower levels of reserve. We hypothesize that the effects of social isolation and loneliness on cognitive function are likely to be moderated by educational level, such that effects are stronger among those with lower levels of education.

We tested the above hypotheses in a large, nationally representative sample of older adults in England by using follow-up data on cognitive function for a period of 4 years.

METHODS

Participants

The English Longitudinal Study of Ageing (ELSA) is a panel study of individuals aged 50 years or older and living in England. The first wave of ELSA in 2002 was composed of respondents to the Health Survey for England, which was designed to be representative of the English population living in private households. Participants in the 1998, 1999, and 2001 Health Survey for England were invited to participate if they were born on or before February 29, 1952 (i.e., they would be 50 years or older by the start of fieldwork for the first wave of ELSA). Participants are followed up every 2 years. Further details regarding sample design and measures are provided elsewhere (34). Ethics approval for ELSA was provided by the London Multicenter Research Ethics Committee.

Wave 2 (2004/2005) was the first wave of ELSA to include a measure of loneliness; hence, this was taken as the baseline wave for this analysis. Participants who dropped out after ELSA Wave 1 were of lower SES, less educated, in poorer health, more likely to be nonwhite, and less socially connected (31,35). Outcomes were assessed at 4 years of follow-up (Wave 4, 2008/2009). At baseline (Wave 2), 8688 participants completed the interview (either fully or partially) in person. Complete data on cognitive function were available for 8630 participants (99%). Follow-up data on measures of cognitive function were available for 6034 participants who are included in the present analysis. When compared with participants who dropped out after our baseline wave, participants included in the current analysis were younger, less lonely, less isolated, less likely to be in the lowest wealth quintile, more likely to be working, and more likely to have a degree or higher education. They were also less likely to report a diagnosis of cardiovascular disease (CVD), diabetes, or depression. Participants who dropped out also had lower scores on verbal fluency, immediate recall, and delayed recall.

Measures

Measures of isolation and loneliness were obtained at baseline.

Social Isolation

A social isolation index was computed, with respondents given points if they were not married/not cohabiting with a partner (scored as 1); had less than monthly contact (including face-to-face, telephone, or written/e-mail contact) with children, other immediate family, and friends (each scored as 1); and they did not participate in any organizations, religious groups, gyms/sports clubs or committees (scored as 1). Scores ranged from 0 to 5, with higher scores indicating greater isolation (31).

Loneliness

The three-item short form of the revised UCLA Loneliness Scale (36) was used as a measure of loneliness. An example of an item used would be "How often do you feel you lack companionship?" (response options are "hardly ever or never," "some of the time," and "often"). The scale showed acceptable internal reliability ($\alpha = 0.78$). Scores on the scale were summed to provide a loneliness score ranging from 3 to 9, with higher scores indicating greater loneliness.

Cognitive Function

ELSA includes several measures of cognitive function, and a detailed description of these measures is available elsewhere (37). For the present analysis, we included two measures of memory and a single measure of executive function. Identical measures were obtained at baseline and at follow-up.

Memory

Participants were presented with a list of 10 words that were read out by a computer at the rate of one word for every 2 seconds. A total of four such lists were available, and these were randomly allocated by the computer. After the presentation of words, participants were asked to recall as many words as they could (immediate recall). Participants were also asked to recall these words after an interval during which they completed other cognitive function tests (delayed recall). The number of correctly recalled words was used as a measure of memory.

Executive Function

Verbal fluency was used as a measure of executive function. Participants were asked to name as many members of a specific category (in this case, animals) as they could in 1 minute. The number of animals named was used as a measure of executive function.

Education

Participants were asked about the highest educational qualification they had obtained. With this information, we classified educational level as low, including participants with no formal qualifications (equivalent to no high school diploma in the United States), and as high, including participants who had O-level, A-level, or higher qualifications (38).

Covariates

Data on all covariates were obtained at baseline. Data on age and sex were collected during the ELSA interview. Wealth was used as the measure of SES, as this has been shown to best capture the material resources available to older adults (39). Wealth was calculated net of debt and included the total value of the participant's home (excluding mortgage), financial assets such as savings, business assets, and physical wealth such as artwork or jewelry. As wealth differs

markedly for couple and single households and as marital status is a component of the social isolation measure, we used marital status–adjusted wealth to ensure that wealth does not act as a proxy for household composition. As working status is likely to be related to loneliness and cognitive function (37,40), we controlled for current employment status, classified as employed (either full time or part time) or not employed (owing to unemployment, illness, or family reasons).

The analyses were also adjusted for depression, as it is associated with isolation and loneliness (41–43) and cognitive function (44). Depression was measured with the eight-item version of the Center for Epidemiologic Studies Depression scale (CES-D). The item on loneliness was not included in our analysis. Scores on the scale were summed, and we used continuous scores on CES-D. The scale has acceptable reliability and validity (45) and has been used extensively in ELSA and in the Health and Retirement Study (46,47). Additional covariates included variables such as diagnosed CVD and diabetes, which are associated with outcomes and key predictors (47–51). Smoking and physical activity, which are also known to be associated with cognitive function (52), isolation, and loneliness (53–55), were also included as covariates.

Statistical Analysis

Measures of cognitive function at follow-up were regressed on to social isolation and loneliness at baseline. At baseline, data were imputed for isolation, loneliness, and covariates. Missing values (for variables imputed: median percentage missing = 0.8%, mean = 2.6%, maximum = 12.1%) were imputed by using the multiple imputation procedure in SAS (PROC MI). Five complete data sets were created and analyzed. Estimates from these analyses were combined by using the MIANALYZE procedure. As results for the analyses carried out on a sample where values were not imputed did not differ substantively from the analyses for the imputed data set, the results of the analysis using the complete (imputed) data set are reported here. All analyses were weighted for nonresponse at follow-up.

Scores on the isolation measure were moderately positively skewed and log transformed. As the loneliness measure was severely positively skewed, we inversed this scale (56) and multiplied the resulting scale by −1 to retain the original order of values. Correlations r (or point biserial correlations r_{pb}, where appropriate) between key predictors and covariates included in the analyses were examined. After this, regression models were run for each of the cognitive function outcomes. Models were run in three steps. The first step included all covariates and baseline cognitive function. Social isolation and loneliness were added in the second step. Each of the interactions was evaluated in separate models, with the social isolation × loneliness interaction added in the final step in one model (Step 3a), the social isolation × education interaction added in the final step in a second model (Step 3b), and the loneliness × education interaction added in the final step in a third model (Step 3c). Note that although all interaction models were fully covariate adjusted, we did not mutually adjust for interactions. For all regression analyses, we report unstandardized regression coefficients (B) with corresponding standard errors. We also report standardized regression coefficients (β) as key predictors, and the main outcomes under study are measured on different scales. To aid the interpretation of significant interactions, we used MODPROBE (57) to obtain predicted values of the outcome variable at different levels of the moderator, using untransformed values of the key predictors. Analyses were carried out using SAS version 9.2 (SAS Institute, Cary, NC) and PASW 18.0.

RESULTS

Table 1 shows the characteristics of the population under study at baseline. The mean age of participants was just over 65 years, and less than half were men. Fifty-three percent of participants reported CVD, whereas 8% had diabetes. Only 1.7% of participants reported the highest possible score on the loneliness scale, and 4.8% of participants were completely isolated. At baseline, the mean score for verbal fluency was 20.3; the mean immediate recall from a list of 10 words was 5.8 words, whereas delayed recall for the same list was 4.4 words. After 4 years, the mean scores on all aspects of cognition were significantly lower (all p values < 0.001).

Relationship With Covariates

Unadjusted correlations between covariates included in the analyses and isolation and loneliness were evaluated. At baseline, age was positively associated with isolation ($r = 0.16$, $p < .001$) and loneliness ($r = 0.06$, $p < .001$). Although isolation was not significantly associated with sex ($r_{pb} = -0.004$, $p = .75$), loneliness was higher among women ($r_{pb} = -0.10$, $p < .001$). Diagnosed CVD was positively associated with isolation ($r_{pb} = 0.08$, $p < .001$) and loneliness ($r_{pb} = 0.08$, $p < .001$), as was diagnosed diabetes ($r_{pb} = 0.04$, $p = .006$ for isolation; $r_{pb} = 0.03$, $p = .03$ for loneliness). CES-D scores were also positively associated with isolation ($r = 0.16$, $p < .001$) and loneliness ($r = 0.40$, $p < .001$). Being in the lowest wealth quintile was positively associated with isolation ($r_{pb} = 0.13$, $p < .001$) and loneliness ($r_{pb} = 0.10$, $p < .001$). Similarly, higher education was associated with lower levels of isolation ($r_{pb} = -0.21$, $p < .001$) and loneliness ($r_{pb} = -0.12$, $p < .001$). Being in work was inversely associated with isolation ($r_{pb} = -0.08$, $p < .001$) and loneliness ($r_{pb} = -0.09$, $p < .001$). Risky health behaviors also showed a positive association with isolation ($r_{pb} = 0.12$, $p < .001$ for smoking; $r_{pb} = 0.17$, $p < .001$ for low levels of activity) and loneliness ($r_{pb} = 0.06$, $p < .001$ for smoking; $r_{pb} = 0.16$, $p < .001$ for low levels of activity).

TABLE 1. Characteristics of the Study Sample (N = 6034)

Variables	Analytical Sample
Age, *M* (SD), y	65.6 (9.5)
Male, %	45.3
CVD, %	53.6
Diabetes, %	8.3
Depression	
CES-D, *M* (SD)	1.4 (1.8)
≥4, %	13.1
In full or part-time work, %	32.9
No formal qualifications, %	39.7
Social isolation	
M (SD)	1.5 (1.4)
Reporting highest possible scores, %	4.8
Loneliness	
M (SD)	4.1 (1.4)
Reporting highest possible scores, %	1.7
Baseline cognitive function, *M* (SD)	
Verbal fluency	20.3 (6.3)
Immediate recall	5.8 (1.7)
Delayed recall	4.4 (2.0)
Follow-up cognitive function (after 4 y), *M* (SD)	
Verbal fluency	19.9 (7.0)
Immediate recall	5.6 (1.8)
Delayed recall	4.3 (2.1)

M = mean; SD = standard deviation; CVD = cardiovascular disease; CES-D = Center for Epidemiologic Studies Depression scale.

TABLE 2. Predicting Verbal Fluency at Follow-up

	Step 1		Step 2		Step 3a		Step 3b		Step 3c	
	B (SE)	β	*B* (SE)	β	*B* (SE)	β	*B* (SE)	β	*B* (SE)	β
Age	−0.15 (0.01)***	−.19	−0.15 (0.01)***	−.19	−0.15 (0.01)***	−.19	−0.15 (0.01)***	−.19	−0.15 (0.01)***	−.19
Male	0.06 (0.14)	.004	0.07 (0.14)	.01	0.07 (0.14)	.01	0.07 (0.14)	.01	0.07 (0.14)	.01
CVD	−0.26 (0.15)	−.02	−0.25 (0.15)	−.02	−0.25 (0.15)	−.02	−0.25 (0.15)	−.02	−0.25 (0.15)	−.02
Diabetes	−0.45 (0.26)	−.02	−0.45 (0.25)	−.02	−0.45 (0.26)	−.02	−0.45 (0.26)	−.02	−0.45 (0.26)	−.02
Depression	−0.18 (0.04)***	−.04	−0.15 (0.04)***	−.04	−0.15 (0.04)***	−.04	−0.15 (0.04)***	−.04	−0.15 (0.04)***	−.04
Wealth	0.28 (0.05)***	.05	0.28 (0.05)***	.05	0.28 (0.05)***	.05	0.28 (0.05)***	.05	0.28 (0.05)***	.05
In work	−0.26 (0.18)	−.02	−0.24 (0.18)	−.02	−0.24 (0.18)	−.02	−0.24 (0.18)	−.02	−0.24 (0.18)	−.02
Current smoker	−0.37 (0.20)	−.02	−0.31 (0.20)	−.02	−0.31 (0.20)	−.02	−0.31 (0.20)	−.02	−0.31 (0.20)	−.02
Low physical activity	−0.54 (0.17)**	−.03	−0.50 (0.17)**	−.03	−0.50 (0.16)**	−.03	−0.50 (0.17)**	−.03	−0.50 (0.17)**	−.03
Low educational level	−1.00 (0.16)***	−.07	−0.94 (0.17)***	−.07	−0.95 (0.16)***	−.07	−0.87 (0.26)***	−.06	−0.93 (0.56)	−.06
Wave 2 verbal fluency	0.56 (0.01)***	.51	0.55 (0.01)***	.50	0.55 (0.01)***	.50	0.55 (0.01)***	.50	0.55 (0.01)***	.50
Isolation[a]			−0.32 (0.13)*	−.03	−0.80 (0.57)	−.03	−0.29 (0.17)	−.02	−0.32 (0.13)*	−.03
Loneliness[a]			−0.82 (1.10)	−.01	0.61 (1.87)	−.01	−0.82 (1.10)	−.01	−0.86 (1.36)	−.01
Isolation × loneliness					−1.77 (2.06)	−.01				
Isolation × education							−0.10 (0.26)	−.004		
Loneliness × education									0.09 (2.03)	.0004
R^2	0.424		0.425		0.424		0.424		0.424	
ΔR^2			0.001		0.000		0.000		0.000	
ΔF	387.17***		3.44*		0.0783		0.097		0.002	

B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient; CVD = cardiovascular disease.
The table presents the results of linear regression analyses on verbal fluency at follow-up.
* $p < .05$.
** $p < .01$.
*** $p < .001$.
[a] Scores on social isolation were log transformed, and scores on loneliness were reflected and inversed.

Relationship Between Social Isolation and Loneliness

In unadjusted analysis, isolation was positively associated with loneliness (B (SE) = 0.03 (0.002), $p < .001$, $\beta = .24$). After adjustment for all covariates, this relationship was attenuated, although isolation was still significantly positively related to loneliness (B (SE) = 0.02 (0.002), $p < .001$, $\beta = .18$).

Associations Between Isolation, Loneliness, and Cognitive Function at Baseline

In mutually adjusted and fully covariate-adjusted models, isolation and loneliness were significantly associated with verbal fluency (B (SE) = −0.80 (0.15), $p < .001$, $\beta = -.07$ for isolation; B (SE) = −4.04 (1.12), $p < .001$, $\beta = -.05$ for loneliness), immediate recall (B (SE) = −0.16 (0.04), $p < .001$, $\beta = -.05$ for isolation; B (SE) = −0.88 (0.33), $p = .007$, $\beta = -.04$ for loneliness), and delayed recall (B (SE) = −0.21 (0.05), $p < .001$, $\beta = -.06$ isolation; B (SE) = −1.16 (0.40), $p < .001$, $\beta = -.06$ for loneliness) at baseline. For both isolation and loneliness, higher scores were associated with poorer cognitive function at baseline.

Are Social Isolation and Loneliness Associated With Change in Cognitive Function?

Tables 2, 3, and 4 show the results of regression on verbal fluency, immediate recall, and delayed recall, respectively. For all outcomes, covariates and baseline cognition were entered in Step 1. Social isolation and loneliness were entered in Step 2. Increasing isolation was associated with lower scores on verbal fluency, immediate recall, and delayed recall after 4 years. Loneliness was associated with lower scores on recall after 4 years; however, the association with verbal fluency was nonsignificant.

Interactions Between Social Isolation and Loneliness

From Step 3a in Table 2, we see that the interaction between isolation and loneliness was nonsignificant for verbal fluency. Step 3a in Tables 3 and 4 shows that this interaction was significant for immediate recall and delayed recall. Examining the effect of loneliness on recall by categories of isolation, we see that recall worsens with increases in loneliness for individuals who are more isolated (Fig. 1, A and B)

Does Education Moderate the Association Between Social Relationships and Cognitive Function?

Step 3b in Tables 2, 3, and 4 shows the results of adding the isolation × education interaction to the fully covariate-adjusted model including isolation and loneliness (Step 2). This interaction term was not significant for verbal fluency or immediate recall but was significant for the delayed recall model. Similarly, the loneliness × education interaction (Step 3c in Tables 2, 3, and 4) was not significant for verbal fluency or immediate recall. For delayed recall, the loneliness × education interaction was significant. Figure 2, A and B, shows that increased isolation and loneliness at baseline do not seem to affect delayed recall at follow-up for individuals in the high-education category. For those in the low-education category, however, higher levels of isolation and loneliness are associated with poorer recall.

DISCUSSION

Despite considerable interest in the effect of social relationships on cognition, findings in this area have remained inconclusive, and this may be attributable to a number of factors, including short follow-up periods and failure to consider important confounders (58). Our results show that social isolation was associated with decreases in verbal fluency, immediate recall, and delayed recall during a 4-year period in a large, nationally representative sample of older adults. Loneliness was significantly associated with poorer recall. We found a significant effect of the isolation × loneliness interaction on recall, such that loneliness was associated with poorer immediate recall and delayed recall at follow-up among those who were more isolated. Our results highlight the need to study the effects of isolation and loneliness simultaneously. As noted previously, one of the mechanisms by which social integration aids cognitive function is by communication and the interaction necessitated by social engagement, as well as by the sense of worth and affiliation provided by fulfilling contacts (13,59–61). Biological mechanisms, such as impaired immune function (62–64), elevated cortisol output (65), inhibition of previously learned responses, and changes in brain biology (66), have also been proposed.

In line with our second hypothesis, our analysis shows that the association of isolation and loneliness with cognitive function is more pronounced in individuals with lower levels of education. Interactions with others may aid functioning by building cognitive reserve (61); this process is likely to be most beneficial among those who otherwise have low levels of reserve, such as individuals with lower levels of education (67). There are parallels with findings for other health outcomes, where the effects of social networks are more marked among those with less education or those on lower incomes. For instance, in the French Gazel cohort, participation in social activities was more strongly related to self-reported health among low-SES participants (68). More recently, Schöllgen et al. (69) found that the effects of social resources on health were stronger for low-income groups. In these participants, social networks and the support they provide act as buffers for those who may have fewer resources to buy or otherwise access services or support. Furthermore, individuals with higher levels of education may spend more of their time reading or engaged in other intellectual pursuits, which may compensate for the lack of social contact.

It has been noted that cognitive ability can be augmented during the life course (32). This has important implications for interventions. For older adults, education is completed much earlier in life, but social networks can be developed even in older age. This could be a useful way to prevent cognitive decline in older adults who are less well educated.

TABLE 3. Predicting Immediate Recall at Follow-up

	Step 1		Step 2		Step 3a		Step 3b		Step 3c	
	B (SE)	β	*B* (SE)	β	*B* (SE)	β	*B* (SE)	β	*B* (SE)	β
Age	−0.05 (0.002)***	−.29	−0.06 (0.002)***	−.29	−0.06 (0.002)***	−.29	−0.06 (0.002)***	−.29	−0.06 (0.003)***	−.29
Male	−0.26 (0.04)***	−.07	−0.26 (0.04)***	−.07	−0.26 (0.04)***	−.07	−0.26 (0.04)***	−.07	−0.26 (0.04)***	−.07
CVD	−0.01 (0.04)	−.002	−0.002 (0.04)	−.001	−0.003 (0.04)	−.001	−0.002 (0.04)	−.001	−0.002 (0.04)	−.001
Diabetes	−0.13 (0.07)	−.02	−0.14 (0.07)	−.02	−0.14 (0.07)	−.02	−0.14 (0.07)	−.02	−0.14 (0.07)	−.02
Depression	−0.04 (0.01)***	−.04	−0.02 (0.01)	−.02	−0.02 (0.01)	−.02	−0.02 (0.01)	−.02	−0.02 (0.01)	−.02
Wealth	0.10 (0.01)***	.08	0.10 (0.01)***	.08	0.10 (0.01)***	.08	0.10 (0.01)***	.08	0.10 (0.01)***	.08
In work	−0.07 (0.05)	−.02	−0.07 (0.05)	−.01	−0.07 (0.05)	−.02	−0.07 (0.05)	−.01	−0.07 (0.05)	−.01
Current smoker	−0.24 (0.06)***	−.05	−0.21 (0.06)***	−.04	−0.21 (0.06)***	−.04	−0.21 (0.06)***	−.04	−0.21 (0.06)***	−.04
Low physical activity	−0.12 (0.05)*	−.03	−0.09 (0.05)*	−.02	−0.09 (0.05)	−.02	−0.09 (0.05)	−.02	−0.09 (0.05)	−.02
Low educational level	−0.44 (0.04)***	−.12	−0.41 (0.04)***	−.11	−0.41 (0.04)***	−.11	−0.35 (0.07)***	−.09	−0.66 (0.15)***	−.11
Wave 2 immediate recall	0.33 (0.01)***	.32	0.33 (0.01)***	.31	0.33 (0.01)***	.31	0.33 (0.01)***	.31	0.33 (0.01)***	.31
Isolation[a]			−0.14 (0.04)***	−.05	−0.56 (0.15)***	−.04	−0.11 (0.05)*	−.04	−0.14 (0.04)***	−.04
Loneliness[a]			−1.30 (0.29)***	−.05	−0.05 (0.51)	−.05	−1.30 (0.29)***	−.05	−0.89 (0.37)*	−.05
Isolation × loneliness					−1.55 (0.54)**	−.03				
Isolation × education							−0.07 (0.07)	−.01		
Loneliness × education									−0.96 (0.54)	−.02
R^2	0.345		0.350		0.351		0.351		0.351	
ΔR^2	276.72***		0.005		0.001		0.000		0.000	
ΔF			22.32***		7.59**		1.04		3.13	

B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient; CVD = cardiovascular disease.
The table presents the results of linear regression analyses on immediate recall at follow-up.
* $p < .05$.
** $p < .01$.
*** $p < .001$.
[a] Scores on social isolation were log transformed, and scores on loneliness were reflected and inversed.

TABLE 4. Predicting Delayed Recall at Follow-up

	Step 1		Step 2		Step 3a		Step 3b		Step 3c	
	B (SE)	β	*B* (SE)	β	*B* (SE)	β	*B* (SE)	β	*B* (SE)	β
Age	−0.06 (0.003)***	−.26	−0.06 (0.003)***	−.26	−0.06 (0.003)***	−.26	−0.06 (0.003)***	−.26	−0.06 (0.003)***	−.26
Male	−0.29 (0.04)***	−.07	−0.29 (0.04)***	−.07	−0.29 (0.04)***	−.07	−0.29 (0.04)***	−.07	−0.28 (0.04)***	−.07
CVD	−0.01 (0.05)	−.003	−0.01 (0.05)	−.002	−0.01 (0.05)	−.002	−0.01 (0.05)	−.002	−0.01 (0.05)	−.002
Diabetes	−0.07 (0.08)	−.01	−0.07 (0.08)	−.01	−0.07 (0.08)	−.01	−0.07 (0.08)	−.01	−0.07 (0.08)	−.01
Depression	−0.08 (0.01)***	−.06	−0.06 (0.01)***	−.05	−0.06 (0.01)***	−.05	−0.06 (0.01)***	−.05	−0.06 (0.01)***	−.05
Wealth	0.07 (0.01)***	.05	0.07 (0.02)***	.05	0.07 (0.02)***	.05	0.07 (0.02)***	.05	0.07 (0.02)***	.05
In work	−0.04 (0.06)	−.01	−0.04 (0.06)	−.01	−0.04 (0.06)	−.01	−0.04 (0.06)	−.01	−0.04 (0.06)	−.01
Current smoker	−0.25 (0.06)***	−.04	−0.23 (0.06)***	−.04	−0.23 (0.06)***	−.04	−0.23 (0.06)***	−.04	−0.23 (0.06)***	−.04
Low physical activity	−0.08 (0.05)	−.02	−0.06 (0.05)	−.01	−0.06 (0.05)	−.01	−0.05 (0.05)	−.01	−0.05 (0.05)	−.01
Low educational level	−0.42 (0.05)***	−.09	−0.39 (0.05)***	−.09	−0.39 (0.05)***	−.09	−0.25 (0.08)**	−.09	−0.75 (0.17)***	−.09
Wave 2 delayed recall	0.44 (0.01)***	.42	0.44 (0.01)***	.41	0.44 (0.01)***	.41	0.44 (0.01)***	.41	0.44 (0.01)***	.41
Isolation[a]			−0.14 (0.04)***	−.04	−0.46 (0.16)**	−.04	−0.07 (0.05)	−.03	−0.15 (0.04)***	−.04
Loneliness[a]			−0.79 (0.34)*	−.03	0.17 (0.56)	−.02	0.80 (0.34)*	−.03	−0.23 (0.42)	−.02
Isolation × loneliness					−1.19 (0.56)*	−.03				
Isolation × education							−0.18 (0.08)*	−.02		
Loneliness × education									−1.34 (0.62)*	−.02
R^2	0.412		0.414		0.415		0.415		0.415	
ΔR^2			0.002		0.001		0.001		0.001	
ΔF	337.79***		12.72***		9.58**		6.48*		7.61*	

B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient; CVD = cardiovascular disease.
The table presents the results of linear regression analyses on delayed recall at follow-up.
* $p < .05$.
** $p < .01$.
*** $p < .001$
[a] Scores on social isolation were log transformed, and scores on loneliness were reflected and inversed.

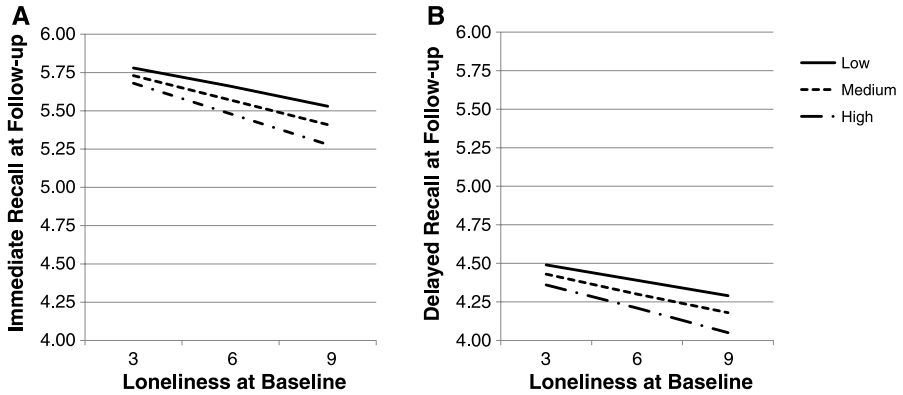

Figure 1. Effect of loneliness on cognitive function by level of social isolation. Number of words recalled at follow-up, adjusted for age, sex, diagnosed cardiovascular disease, diabetes, depression, marital status-adjusted wealth, smoking, physical activity, work status, and Wave 2 recall.

Study Strengths and Limitations

ELSA is a large, multidisciplinary study with a nationally representative sample of older adults. As a result, we were able to obtain detailed measurements not only for cognitive function and social relationships but also for multiple confounding variables. We were able to use a multidimensional measure of isolation by incorporating marital status, network size, and activity. Multiple connections and activities may be relevant to cognitive function; hence, such measures are more appropriate for studying the effects of social relationships on cognitive function (19). However, in this analysis, we weighted all relationships and each dimension of isolation equally, and these may vary in importance for individuals (31,70). Alcohol consumption and fruit/vegetable consumption have been found to affect cognitive function (52). However, no measure of diet was available in Wave 2, and the measure of alcohol consumption had a very high proportion of missing values and hence could not be included in the analysis. The measures of cognitive function in this study were somewhat limited by the time constraints present in a large-scale multipurpose study like ELSA. The measures were similar to those used in other population-based surveys of older adults, such as the Health and Retirement Study. In addition, the cognitive variables have been shown to be relevant to the everyday functioning of older adults, being associated with health literacy (71), second-hand smoke exposure (72), investment decisions after retirement (73), and stroke risk (74).

A further limitation of our study was the dropout after our baseline wave. The sample analyzed here was healthier, wealthier, more socially connected, less lonely, and had better cognitive function than those who dropped out. As such, the findings are likely to be generalizable to healthy older adults. Although the analyses were weighted to correct for nonresponse, the weights may not have included all relevant variables. In light of these biases, the estimates presented herein might reflect a conservative estimate of the true associations. Differences in cognitive function between individuals with differing levels of isolation and loneliness exist at baseline. The effects seen here may precede study onset, although this study evaluates changes in cognition during a 4-year follow-up period.

CONCLUSIONS

Social isolation and loneliness were significantly associated with poorer cognitive function in older adults during a 4-year period. There is now a considerable body of research indicating

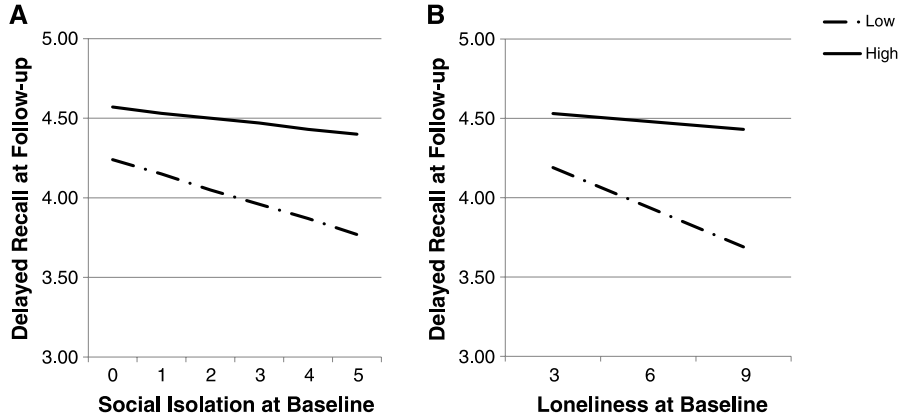

Figure 2. Effect of social isolation and loneliness on delayed recall at follow-up by educational category. Number of words recalled in the delayed recall test at follow-up, adjusted for age, sex, diagnosed cardiovascular disease, diabetes, depression, marital status-adjusted wealth, smoking, physical activity, work status, and Wave 2 recall.

the benefits of a socially integrated life-style. Although interventions to reduce isolation and loneliness have typically shown only limited effectiveness (75), further work in this area is likely to have important public health benefits, particularly among individuals with low levels of education.

The English Longitudinal Study of Ageing was developed by a team of researchers based at University College London, the Institute of Fiscal Studies, and the National Centre for Social Research.

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