Objectives: There is a lack of longitudinal studies, which are both based on nationally representative samples and use standardized instruments to quantify social isolation. Thus, the purpose of this study was to determine the link between perceived social isolation and cognitive functioning longitudinally.

Methods/Design: Longitudinal data with \( n = 6420 \) from 2014 (wave 5) to 2017 (wave 6) were drawn from the German Ageing Survey (nationally representative sample of individuals aged 40 years and over). Perceived social isolation was assessed using a scale by Bude and Lantermann. Cognitive functioning was quantified using the established digit symbol test. To reduce the problem of unobserved heterogeneity, linear fixed effects regressions were used.

Results: Regressions showed that increases in perceived social isolation were associated with decreases in cognitive functioning. With regard to covariates, decreases in cognitive functioning were associated with increases in aging and worsening self-rated health, whereas changes in marital status, employment status, income, physical functioning, and physical illnesses were not associated with the outcome measure.

Conclusions: Based on a nationally representative sample and exploiting the panel data structure, the study findings extend current knowledge by showing that increasing perceived social isolation contributes to decreases in cognitive functioning among individuals aged 40 years and over longitudinally. Future longitudinal studies based on panel data methods are required to validate the study findings.

KEYWORDS
cognition, cognitive functioning, social disconnectedness, social exclusion, social isolation

1 INTRODUCTION

It is widely acknowledged that there is an ongoing change in the demographic structure of industrialized countries, meaning that the number of individuals in late life is increasing continuously. It is also widely understood that age is associated with decreases in cognitive functioning. Moreover, higher age is associated with increased social isolation. Cognitive functioning and social isolation are both associated with subsequent morbidity and mortality, highlighting the importance of these factors.

Social isolation is linked to decreased social activities or social engagement, which, in turn, can stimulate cognitive functioning. An association between social isolation and cognitive functioning has been demonstrated by recent cross-sectional and longitudinal studies. For example, it has been shown that social isolation is related to decreased cognitive function based on data from a Spanish nationally representative sample (\( n = 1691 \); individuals \( \geq 50 \) years; two waves). Similar findings were made by Evans et al based on longitudinal data from the Cognitive Function and
Ageing Study—Wales (n = 1524; individuals aged 65 years and over; two waves).

A recent systematic review on the longitudinal association between social isolation and cognitive functioning showed that these factors are weakly associated. However, most of these longitudinal studies focused on social network and social activities without using standardized instruments (eg, using living alone as a surrogate for social isolation). Thus, this review also observed that there is a lack of longitudinal studies, which are both based on nationally representative samples and use standardized instruments to quantify social isolation. Furthermore, to date, we are only aware of one very recent study that has used linear fixed effects (FE) regression analysis to study the determinants of cognitive functioning over time. This recent study investigated the longitudinal link between financial hardship and cognition using the FE regression analysis.

Using the FE regression analysis in studying the link between perceived social isolation and cognitive functioning over time has the advantage of reducing the problem of unobserved heterogeneity (eg, genetic disposition), which is a serious concern when analyzing data from large survey studies. For example, it is commonly not possible to adjust for differences in genetic factors between individuals in survey studies (for several reasons). Using FE regressions, scientists do not have to be concerned about these discrepancies in time-constant (ie, factors that do not vary within individuals over time such as genetic factors) unobserved factors. Using within-variation over time (ie, changes within individuals over time; eg, changes in social isolation within an individual over time), FE regressions exploit the panel data structure of the dataset used (for further details: please see the Section 2 as well as Brüderl and Ludwig). Therefore, the purpose of this study was to examine the longitudinal association between perceived social isolation and cognitive functioning based on a nationally representative sample using the FE regression analysis.

2 | METHODS

2.1 | Sample

For this study, data were drawn from wave 5 (2014) to wave 6 (2017) from the German Ageing Survey (DEAS), a nationally representative sample of individuals aged 40 years and over, which is funded by the Federal Ministry for Family Affairs, Senior Citizens, Women, and Youth in Germany. In this survey, topics such as perception of age, social relationships, voluntary engagement, health-related factors, or well-being are included. Starting in 1996 (first wave), further waves have taken place in 2002 (second wave), 2008 (third wave), 2011 (fourth wave), 2014 (fifth wave), and 2017 (sixth wave). DEAS has a cohort-sequential design, which means that new baseline samples were introduced in the second, third, and fifth waves. While more than 10 300 individuals took part in the fifth wave, more than 6600 individuals were interviewed in the sixth wave. For example, in the most recent wave, the response rate was 63%, which is comparable to other survey studies performed in Germany. Because perceived social isolation was only quantified from wave 5 onward, we used waves 5 and 6 in our study. Further details with regard to the DEAS study are provided by Klaus et al. Written informed consent was provided by all participants. Because the criteria for an ethical statement were not fulfilled (such as risk for the respondents or use of invasive methods), an ethics committee approval was not required.

2.2 | Dependent variable

The digit symbol test, adapted from the digit symbol substitution test, was used to measure cognitive functioning. It measures perceptual motor speed and processing speed of visual perception and information. Ranging from 1 to 92, higher scores reflect better cognitive functioning. Numerous previous studies focusing on the determinants of cognitive functioning have used it. Furthermore, it has been demonstrated that its psychometric characteristics are sound.

2.3 | Independent variables

A scale developed by Bude and Lantermann was used to quantify perceived social isolation. It has four items (each item ranges from 1 [strongly agree] to 4 [strongly disagree]). The mean rating across all items was computed, with higher values corresponding to higher social isolation. In our study, Cronbach’s alpha was .88.

Age, family status (married, and living together with spouse), others (married, and living separated from spouse, single, divorced, widowed), household net equivalent income (in Euro), as well as labor force participation (employed, retired, other [not employed]) were adjusted for in the analysis. Furthermore, self-rated health (from 1 = very good to 5 = very bad), physical functioning (using the “physical functioning” subscale of the SF-36; ranging from 0 [worst] to 100 [best]), and the number of physical illnesses (eg, diabetes; sum score ranges from 0 to 11 physical illnesses) were adjusted for in the analysis.
In a sensitivity analysis, the number of important people in regular contact (ranging from 0 to 9), loneliness (using the widely used De Jong Gierveld scale\textsuperscript{18}, ranging from 1 to 4; higher values correspond to higher loneliness), and depressive symptoms using the established 15-item version of the Center for Epidemiologic Studies Depression Scale\textsuperscript{19}, which ranges from 0 (which corresponds to no depressive symptoms) to 45 (reflecting severe depressive symptoms), were adjusted for.

It is worth noting that perceived social isolation is correlated with network size and loneliness. However, these are distinct concepts.\textsuperscript{20} For example, individuals can perceive themselves as socially isolated without feeling lonely and while having a large network of frequent and close personal relationships (or vice versa).\textsuperscript{21}

2.4 Statistical analysis

In large survey studies, it is almost impossible to control for unobserved time-constant factors such as genetic differences. However, when these unobserved time-constant factors are associated with the explanatory variables, many panel regressions models yield inconsistent estimates. By contrast, FE regression produce consistent estimates (ie, an estimator that converges in probability to the true value of the parameter as the sample size goes to infinity) even if time-constant unobserved factors are systematically correlated with the independent variables. Sargan-Hansen tests (equivalent to Hausman tests with robust SEs) encouraged our statistical choice (eg, in the main model: Sargan-Hansen statistic = 77.73, $P < .001$).

A main characteristic of the FE estimator is that the only changes within individuals over time are included (eg, changes in perceived social isolation within individuals from 2014 to 2017). This also means that factors that are constant over time (eg, sex or education) cannot be used as regressors in the FE regression analysis. Cluster-robust SEs were computed.\textsuperscript{22} The significance level was set at $P < .05$. Stata 15.1 (StataCorp, College Station, TX) was used in the current study.

3 RESULTS

3.1 Sample characteristics

We described observations included in the FE regression analysis in Table 1. In the analytical sample, 50.3% were women and average age was 65.0 years (SD: 10.7). The average perceived social isolation score was 1.6 (SD: 0.6), and the average cognitive functioning score was 64.5 years (SD: 13.3). Further details are described in Table 1.

3.2 Regression analysis

Following the recommendations of Cameron and Trivedi,\textsuperscript{23} we first tested whether our variables of interest have enough within variation to obtain precise estimates ("xttab" and "xtrans" commands in Stata).

| TABLE 1 Sample characteristics for individuals (n = 6420 observations) included in linear fixed effects regressions (wave 5 to wave 6, pooled) |
|-------------------------------------------------|
| Female: N (%)                                   | 3228 (50.3%) |
| Education (ISCED-97): N (%)                     |              |
| Low education                                   | 274 (4.3%)   |
| Medium education                                | 3144 (49.0%) |
| High education                                  | 3002 (46.7%) |
| Age (in years): Mean (SD)                       | 65.0 (±10.7) |
| Married, living together with spouse: N (%)     | 4530 (70.6%) |
| Employment status: N (%)                        |              |
| Employed                                        | 2369 (36.9%) |
| Retired                                         | 3590 (55.9%) |
| Other: not employed                             | 461 (7.2%)   |
| Household net equivalent income (in Euro)       | 2082.5 (±1392.4) |
| Self-rated health (from 1 = very good to 5 = very bad): Mean (SD) | 2.4 (±0.8) |
| Physical functioning (from 0 [worst] to 100 [best]): Mean (SD) | 83.6 (±21.0) |
| Number of physical illnesses (from 0 to 11): Mean (SD) | 2.5 (±1.9) |
| Social isolation (from 1 to 4; higher values correspond to higher social isolation): Mean (SD) | 1.6 (±0.6) |
| Cognitive functioning (empirical range from 0 to 92; higher values correspond to higher cognitive functioning): Mean (SD) | 64.5 (±13.3) |

Note: The variables sex and education were not included in FE regressions as independent variables since they are time-constant. These two variables are only depicted for descriptive purposes.

Afterward, a series of FE regressions were conducted. In the main regression analysis (see Table 2) (n = 6420 observations), increases in perceived social isolation were associated with decreases in cognitive functioning ($\beta = -1.13, P < .01$). With regard to covariates, decreases in cognitive functioning were associated with increases in aging ($\beta = -.31, P < .001$) and worsening self-rated health ($\beta = -.63, P < .01$), whereas changes in marital status, employment status, income, physical functioning, and physical illnesses were not associated with the outcome measure.

In the sensitivity analysis, our main model was extended by adding the network size, loneliness, and depressive symptoms as covariates. However, the strength of the link between perceived social isolation and cognitive functioning was similar ($\beta = -1.00, P = .01$). Furthermore, it is important to note that decreases in cognitive functioning were not associated with changes in network size ($\beta = .06, P = .32$), changes in loneliness ($\beta = -.08; P = .86$), and changes in depressive symptoms ($\beta = -.02, P = .59$). We also tested whether sex moderates the link between perceived social isolation and cognitive functioning; however, the interaction term (sex x social isolation) did not achieve statistical significance ($P = .34$).
The purpose of this study was to determine the association between perceived social isolation and cognitive functioning using a longitudinal approach based on data from a nationally representative sample of older adults in Germany. FE regressions revealed that increases in perceived social isolation were associated with decreases in cognitive functioning. With regard to covariates, decreases in cognitive functioning were associated with increases in aging and worsening self-rated health, whereas changes in marital status, employment status, income, physical functioning, and physical illnesses were not associated with the outcome measure.

### 4.1 Main findings

The underlying mechanisms of this association are largely unknown. A possible explanation may be that social isolation is associated with infrequent social activities that stimulate cognitive functioning.4 This is in line with the three hypotheses provided by Fratiglioni et al24 namely the (i) cognitive reserve hypothesis, (ii) vascular hypothesis, and (iii) stress hypothesis. Each hypothesis outlines the possible ways in which lifestyle factors shape cognitive function.

(i) Active lifestyles (in terms of the absence of social isolation as well as mental and physical factors) can increase cognitive reserve (cognitive reserve hypothesis) by increasing the resilience of an individual to neuropathological damage. The underlying idea is, therefore, that individuals differ in the ability to cope with Alzheimer’s disease (AD) pathology. The cognitive reserve hypothesis is supported by the robust finding of a link between low education and increased risk of dementia and AD.24 According to Fratiglioni et al,24 cognitive reserve might be facilitated by a better skill to use alternative brain networks as required or by more efficient use of brain networks.

(ii) The vascular hypothesis proposes that the aforementioned lifestyle factors such as social isolation can be beneficial for stroke as well as for cardiovascular diseases,25 which can ultimately lead to decreases in cognitive functioning. For example, several epidemiological studies have shown that vascular risk factors and vascular disorders are linked to decreases in cognitive functioning.24

(iii) According to the stress hypothesis, health-promoting behaviors can avoid social isolation and can increase social engagement, social integration, or social relationships, which can reduce stress, increase relaxation, or enhance self-esteem (as well as other health-related factors).26-28 For example, increased stress is associated with decreases in cognitive functioning.29

Another explanation was proposed by Cacioppo et al30 They assumed that social isolation reduces sleep quality and activates neurobiological mechanisms that can stimulate the hypothalamic-pituitary-adrenocortical axis.31 These processes might affect cognitive functioning.

### 4.3 Strengths and limitations

This is one of a few longitudinal studies investigating the link between perceived social isolation and cognitive functioning. Data were drawn from a nationally representative sample of middle aged and older adults. A main challenge in survey studies—the problem of unobserved heterogeneity—was mitigated using the FE regression analysis. Both our main independent variable (perceived social isolation) and our outcome measure (cognitive functioning) were assessed using widely used scales. However, a published validation study (perceived social isolation) is missing. Several potential confounders were adjusted for in the analyses. Only a small sample selection bias has been identified in the DEAS study.13 The possibility of selection bias cannot be entirely dismissed. Furthermore, decreases in cognitive functioning can lead to increases in social isolation (endogeneity). However, clarifying the directionality of this link requires, for instance, the use of other statistical techniques (eg, instrumental variable techniques). The validity of these techniques greatly depends on using a strong instrument. However, identifying good instruments is difficult, and weak instruments
lead to severely biased estimates. For this reason, FE regressions were used in the present study.

5 | CONCLUSION

Based on a nationally representative sample and exploiting the panel data structure, the study findings extend current knowledge by showing that increasing perceived social isolation contributes to decreases in cognitive functioning among individuals aged 40 years and over longitudinally. Future longitudinal studies based on panel data methods are required to validate the study findings.

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This research did not receive any funding from agencies in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used in this study are third-party data. The anonymized datasets of the DEAS (1996, 2002, 2008, 2011, 2014, and 2017) are available for secondary analysis. The data have been made available to scientists at universities and research institutes exclusively for scientific purposes. The use of data is subject to written data protection agreements. Microdata of the DEAS are available free of charge to scientific researchers for nonprofit purposes. The FDZ-DZA provides access and support to scholars interested in using DEAS for their research. However, for reasons of data protection, signing a data distribution contract is required before data can be obtained. Please see for further information (data distribution contract): https://www.dza.de/en/fdz/access-to-data/formular-deas-en-english.html. Written informed consent was provided by all participants. The DEAS study is in accordance with the Helsinki declaration. Because the criteria for an ethical statement were not fulfilled (such as risk for the respondents or use of invasive methods), an ethics committee approval was not required.

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