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Household-Based Social Isolation and Domain-Specific Cognitive Performance among Older U.S. Adults

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Abstract. This study examined whether household-based social isolation was associated with domain-specific cognitive performance among noninstitutionalized U.S. adults aged 60 years and older in the 2011–2014 National Health and Nutrition Examination Survey (NHANES). Social isolation was classified from marital or partnership status and household size as low, intermediate, or high. Cognitive outcomes included episodic verbal memory measured by CERAD4, processing speed measured by the Digit Symbol Substitution Test (DSST), and semantic fluency measured by Animal Fluency. These scores were standardized using survey-weighted means and standard deviations. A survey-weighted linear regression was also used for the complex sampling design. The final analysis included 2,681 participants. Before adjustment, the intermediate-isolation group scored lowest in all three domains. Scores in the high-isolation group were closer to those in the low-isolation group. After adjustment for demographic and socioeconomic characteristics, only the intermediate-isolation difference in processing speed remained statistically significant at −0.108 standard deviations. Design-based Wald tests did not detect significant differences in isolation coefficients across the three cognitive domains after adjustment. These findings indicate that household composition alone may not capture the broader social relationships relevant to cognition and highlight the need for longitudinal studies using measures of contact frequency, network size, perceived support, depressive symptoms, and functional limitation.

Keywords: Social isolation, Cognitive performance, Older adults, NHANES, Survey-weighted analysis

1. Introduction

Age-related differences in cognitive performance can vary across memory, processing speed, and verbal fluency. Older adults can differ in how well they learn and retrieve new information, how rapidly they process visual material, and how efficiently they reach stored semantic knowledge. Research that only takes one global score into account could conceal domain-specific patterns. The distinction matters for dementia prevention, where social isolation is among the modifiable risk factors mentioned by the Lancet Standing Commission [1], even though cognitive test performance in a cross-sectional survey is not equivalent to a clinical diagnosis.

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Isolation and loneliness are related but separate concepts. Social isolation is the objective condition of having few relationships or infrequent contact [2]. Living alone or lacking a partner increases the risk of isolation without establishing that it has occurred. Some people who live alone remain embedded in family, friendship, or religious networks, and some who live with others are socially disconnected. Partnership status and household size may indicate social isolation, but they do not directly measure loneliness or relationship quality.

Several mechanisms could link weak social structure to poorer cognition. Conversation demands language production, memory retrieval, attention, perspective taking, and quick responses to shifting information, so reduced interaction may lead to less regular stimulation. Disconnection may also work indirectly, through depressive symptoms, inactivity, disrupted sleep, or chronic stress. These pathways are related but unmeasured here, and a cross-sectional survey cannot separate them causally.

Earlier research generally finds a link between weaker social ties and poorer cognition, though its size varies. A review of 65 studies found a small overall association, and the associations for general cognition, memory, and executive function were similar in size [3]. The review also noted that studies measured social contact in very different ways, so it remains unclear whether one ability is more sensitive.

Differences between abilities are still possible. The three tests measure different things: recalling material just learned, scanning and responding quickly, and searching through stored knowledge. Social contact might help word retrieval more than delayed recall, while stress or poor health might show up most in speed. The problem is that the tests use very different scoring ranges, so their raw coefficients cannot be compared. Each score is therefore standardized. They have been converted into standard-deviation units, so the three sit on the same scale.

The National Health and Nutrition Examination Survey (NHANES) 2011–2014 is well-suited to this question. Adults aged 60 and older took the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) Word Learning Test, the Digit Symbol Substitution Test (DSST), and the Animal Fluency Test [4]. The survey also records marital status, household size, education, income, and race and ethnicity. It also supplies weights, strata, and sampling units, which are needed because NHANES does not sample everyone with equal probability. NHANES is also cross-sectional, meaning everything is measured at a single point in time. A recent study of the same years used a wider isolation index and found especially large Digit Symbol differences among the most isolated participants [5]. This study is narrower, as it uses only household structure, and aims to compare the three tests directly.

Recent reviews and longitudinal studies likewise associate social isolation or loneliness with poorer cognitive outcomes in later life, while emphasizing heterogeneity in exposure definitions, possible bidirectionality, and the value of longitudinal designs [6-10].

The study has two aims. The first is to estimate how household-based isolation relates to memory, speed, and fluency. The second is to test whether those three relationships differ from each other. Adults with high isolation are expected to score lower than partnered adults living with others. Low isolation was the reference category, giving two comparisons: intermediate versus low isolation and high versus low isolation. H_0: Within each isolation comparison, the regression coefficients are equal across all three cognitive domains. H_a: For at least one isolation comparison, the regression coefficients differ between at least two cognitive domains. These hypotheses were tested jointly using a design-based Wald F test with four contrasts at the 0.05 significance level.

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2. Materials and methods

The study used public-use, cross-sectional data from the 2011–2012 and 2013–2014 cycles of the National Health and Nutrition Examination Survey (NHANES). The demographic files DEMO_G and DEMO_H provided exposure variables, covariates, examination weights, masked variance strata, and masked primary sampling units (PSUs). The cognitive files CFQ_G and CFQ_H provided Consortium to Establish a Registry for Alzheimer's Disease (CERAD) scores, Animal Fluency, and DSST scores. Records were linked within each cycle using the unique respondent identifier SEQN.

The study focused on participants aged 60 and older who were eligible for the cognitive component. NHANES did not record data from participants who required proxy respondents or who could not complete the assessments in an available language. Moreover, not every eligible participant completed every assessment. The Centers for Disease Control and Prevention (CDC) warns that cognitive-component nonresponse varies by age, education, race and ethnicity, and other characteristics and may be associated with cognitive function itself [11, 12]. The analytic sample and the possibility of selection bias will therefore be described explicitly.

The data were divided into four files, with G representing the 2011–2012 cycle and H representing the 2013–2014 cycle. A positive mobile examination center (MEC) examination weight was applied to all participants through the complex survey design. Restrictions were then imposed for age 60 years or older and complete cognitive observations. This domain-analysis approach retained the full strata and PSU information required for design-based variance estimation. Simply inner-joining to completed cognitive tests before defining the design could produce incorrect standard errors.

The two cycles contained 19,931 participants, of whom 19,151 completed the MEC examination. After restriction to adults aged 60 years or older, 3,472 participants remained. Among them, 2,934 had complete CERAD4, Animal Fluency, and DSST scores, 2,930 also had a valid household-structure classification, and 2,681 had complete values for the proposed socioeconomic covariates, including the family income-to-poverty ratio.

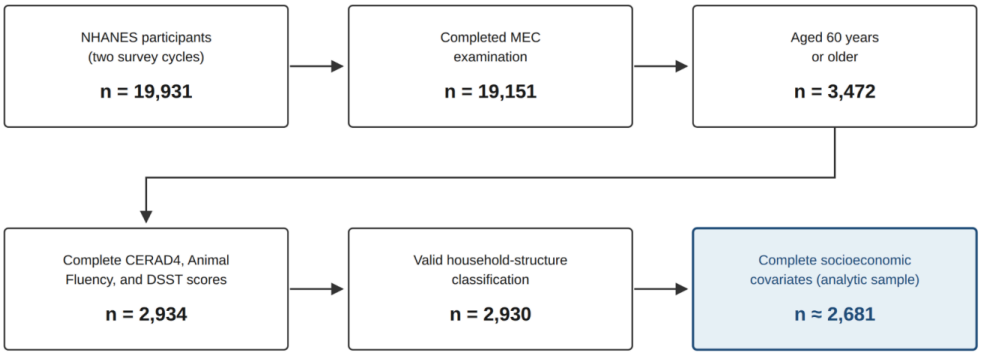


Figure 1. Derivation of the analytic sample, NHANES 2011–2014 (picture credit: original)

Structural isolation was defined from two household-based NHANES variables as shown in Figure 1, marital or partnership status (DMDMARTL) and household size (DMDHHSIZ), combined into a three-level exposure: low (partnered and living with at least one other person), intermediate (exactly one condition, unpartnered while co-resident or living alone while partnered), and high (unpartnered and living alone), with unweighted counts of 1,665, 549, and 716 among the 2,930

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participants who had a valid classification, and 1,521, 484, and 676 in the final analytic sample. It was modeled categorically because the step from low to intermediate cannot be assumed to be the same as the step from intermediate to high. It also remained a proxy for household composition, not loneliness, contact frequency, relationship quality, or support.

Three continuous outcomes represented complementary domains: episodic verbal memory (CERAD4, three immediate-recall trials plus delayed recall, range 0-40), processing speed (DSST), and semantic fluency (Animal Fluency). Because their raw ranges differed, all three were standardized within the common analytic sample using survey-weighted means and standard deviations. This ensures that every coefficient represents a difference in domain-specific standard deviations and that magnitudes are comparable across domains.

Covariates were selected in advance, before adjusted results were examined, and added in two steps. The demographic model controls for age group (60-69, 70-79, 80 or older, grouped because NHANES records age only up to 80), sex, race and Hispanic origin, place of birth, test language, and survey cycle. The socioeconomic model then adds education and income-to-poverty ratio. Both shape who a person lives with and how well they perform on the tests. But income can also follow from widowhood, so adjusting for it may remove part of the association being studied. Comparing the models shows how the estimates change after socioeconomic adjustment. Depressive symptoms and disability are missing from the dataset, and would not be added automatically, since several such variables may lie on the pathway from isolation to cognition.

Because two survey cycles were combined, all estimates used a four-year examination weight, WTMEC4YR = WTMEC2YR / 2, with SDMVSTRA as the stratum variable and SDMVPSU as the cluster variable [13]. Standard errors, confidence intervals, and Wald tests were obtained via Taylor-series linearization. These parts do different jobs. The weight makes the sample represent the national population, since some groups were sampled more heavily and not everyone responded. The strata and clusters do not change the estimates. They correct the margin of error, because NHANES samples people in geographic clusters rather than one by one. Using the weights without them would give sensible averages but standard errors that are too small. Descriptive results paired unweighted counts with weighted percentages, means, and 95% confidence intervals. The p-values were not used to choose covariates.

Analysis proceeded in three stages. The analytic sample was first described overall and within each isolation category, pairing unweighted counts with weighted percentages and weighted means with 95% confidence intervals. Each of the three standardized outcomes was then regressed on the three-level isolation variable using survey-weighted linear regression, with low isolation as the reference category, in three specifications: unadjusted, the demographic model, and the socioeconomic model. Every coefficient is therefore read as a difference in domain-specific standard deviations between an isolation category and the reference. The cross-domain comparison was conducted by stacking the three standardized outcomes into one file, so that each participant contributes three records, and fitting a single model in which every coefficient is allowed to differ by domain. Because the records belonging to one person fall inside the same primary sampling unit, the correlation between a person's three scores is already absorbed by the variance estimator and needs no separate adjustment. The null hypothesis that the isolation coefficients were equal across memory, processing speed, and fluency was tested with a two-sided design-based Wald F test on four contrasts, evaluated at the 0.05 level against the design degrees of freedom. Two sensitivity analyses were conducted: separating the two household arrangements that the intermediate category combines, and refitting the demographic model on every participant with a valid exposure value, so that the effect of excluding people with missing socioeconomic data can be seen directly. These

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cross-sectional analyses do not establish temporal direction; longitudinal evidence has documented associations between social isolation and later memory decline [14].

3. Results

The analytic sample contained 2,681 adults aged 60 and older, representing an estimated 49.8 million noninstitutionalized U.S. adults in that age range. The survey design had 32 degrees of freedom. The numerator and denominator degrees of freedom used for each Wald F test are reported alongside its statistic. Low isolation was by far the most common arrangement, covering 1,521 participants and 64.0% of the weighted population (95% CI 61.7 to 66.2). A further 676 participants were unpartnered and living alone, giving 23.4% (95% CI 21.3 to 25.7) in the high category, and 484 participants fell into the intermediate category, or 12.6% (95% CI 11.1 to 14.3). The intermediate group was almost entirely one arrangement rather than two: 462 of its 484 members were unpartnered but living with at least one other person, whereas only 22 were partnered while living alone. This imbalance matters for how the middle category should be interpreted.

Table 1 summarizes the characteristics of the analytic sample and shows differences in age, sex, education, and income across the three isolation groups. Adults in the low-isolation group were the youngest, with a weighted mean age of 68.5 years against 69.7 in the intermediate group and 70.6 in the high group, and only 10.4% of them were aged 80 or older, compared with 19.9% and 22.2%. Both of the more isolated categories were disproportionately female: women comprised 75.8% of the intermediate group and 68.3% of the high group, compared with 44.8% of the low group, a pattern consistent with widowhood and differential survival. The socioeconomic gap was concentrated in the intermediate category. Its weighted mean family income-to-poverty ratio was 2.29 (95% CI 2.06 to 2.52), against 3.50 in the low group and 2.50 in the high group, and 13.5% of it had less than a ninth-grade education, roughly three times the 4.2% and 4.6% seen in the other two groups. Non-Hispanic Black adults made up 17.9% of the intermediate group but 5.4% of the low group.

Weighted mean scores in the analytic sample were 25.98 on CERAD4 (SD 6.40), 18.20 on Animal Fluency (SD 5.70), and 52.07 on the DSST (SD 16.71); these are the values used to standardize each outcome. Across the three categories the raw scores did not fall in the expected order. On the DSST the low group averaged 53.79 (95% CI 52.54 to 55.03), the high group 51.04 (95% CI 49.00 to 53.09), and the intermediate group 45.21 (95% CI 43.16 to 47.26). The same shape appeared on CERAD4 (26.36, 25.71, and 24.51) and on Animal Fluency (18.63, 17.96, and 16.44). In every domain the lowest mean belonged to the middle category, not to the adults who were both unpartnered and living alone.

As shown in Table 2, the unadjusted regression results followed the same pattern, with the intermediate-isolation group scoring lower than the low-isolation group across all three cognitive domains. Relative to low isolation, the intermediate group scored 0.290 SD lower on memory (95% CI -0.459 to -0.121, $p = 0.001$), 0.386 SD lower on fluency (95% CI -0.508 to -0.263, $p < 0.001$), and 0.513 SD lower on processing speed (95% CI -0.638 to -0.388, $p < 0.001$). The high-isolation group sat much closer to the reference: 0.102 SD lower on memory (95% CI -0.227 to 0.023, $p = 0.106$), 0.119 SD lower on fluency (95% CI -0.259 to 0.022, $p = 0.095$), and 0.164 SD lower on processing speed (95% CI -0.297 to -0.031, $p = 0.017$), so only the speed difference reached significance. The joint test that both isolation coefficients were zero was rejected for all three outcomes, with the smallest statistic being $F(2,31) = 5.92$ for memory ($p = 0.007$).

Figure 2 shows that the estimated differences in cognitive performance between isolation groups generally became smaller after adjustment for demographic and socioeconomic factors. In the

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demographic model the intermediate coefficients fell to -0.250 SD for memory (95% CI -0.412 to -0.088), -0.171 SD for fluency (95% CI -0.295 to -0.048), and -0.320 SD for processing speed (95% CI -0.409 to -0.230), all still significant, while every high-isolation coefficient moved to within 0.08 SD of zero and none remained significant. Adding education and the income-to-poverty ratio attenuated the estimates further. In the socioeconomic model the intermediate coefficient was -0.144 SD for memory (95% CI -0.309 to 0.020, p = 0.083), -0.050 SD for fluency (95% CI -0.174 to 0.074, p = 0.414), and -0.108 SD for processing speed (95% CI -0.198 to -0.018, p = 0.020). Processing speed was the only association that survived full adjustment, and 0.108 SD corresponds to about 1.8 DSST points, which is a small difference on a test scored from 0 to 105. The high-isolation coefficients in that model were -0.002 SD for memory, 0.085 SD for fluency, and 0.063 SD for speed, none of them distinguishable from zero and two of them positive. The covariates that absorbed the difference were strong predictors in their own right: relative to a high school graduate, adults with less than a ninth-grade education scored 0.688 SD lower on the DSST (95% CI -0.819 to -0.557), and each unit of the income-to-poverty ratio was worth 0.124 SD (95% CI 0.092 to 0.156).

The second aim was to test whether the three associations differed from each other, and the analysis did not detect statistically significant differences across domains. In the stacked model the four contrasts comparing the isolation coefficients across domains gave F (4,29) = 2.12, p = 0.104 without adjustment, F (4,29) = 1.69, p = 0.179 in the demographic model, and F (4,29) = 0.81, p = 0.531 in the socioeconomic model. The null hypothesis of equal coefficients was not rejected at any stage, and the evidence weakened rather than strengthened as covariates were added. One narrower comparison came closer. Within the intermediate category before adjustment the three coefficients did differ (F (2,31) = 4.40, p = 0.021), because processing speed sat 0.223 SD further from zero than memory (95% CI -0.380 to -0.067, p = 0.007). That contrast lost significance once demographics and socioeconomic position were in the model, so the hint that speed is the most sensitive domain rests on an unadjusted comparison and should not be read as a finding.

Both sensitivity analyses supported the main results. Splitting the intermediate category confirmed that it behaves as a single group: the 462 unpartnered co-resident adults showed unadjusted differences of -0.285 SD for memory, -0.405 SD for fluency, and -0.539 SD for processing speed, essentially reproducing the combined estimates, and kept a fully adjusted speed difference of -0.129 SD (95% CI -0.222 to -0.036, p = 0.008). The 22 partnered adults living alone were too few to estimate anything usefully. Refitting the demographic model on all 2,930 participants with a valid exposure value gave very similar results (intermediate: -0.227 SD memory, -0.158 SD fluency, -0.291 SD speed), so the exclusions for missing covariates did not create the pattern. Those exclusions were not random, however. The 249 participants dropped for missing education or income were less educated than those retained (17.4% with less than a ninth-grade education against 10.7%) and scored lower on every test, with an unweighted mean DSST of 42.9 against 45.9. Together with the cognitive-component nonresponse described earlier, this means the analytic sample is healthier and better off than the population it is weighted to represent.

Table 1. Characteristics of the analytic sample by household-based isolation category, NHANES 2011–2014

Characteristic	Overall	Low isolation	Intermediate	High isolation
n (unweighted)	2,681	1,521	484	676
Weighted %	100	64.0	12.6	23.4

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Table 1. (continued)

Age, weighted mean (95% CI)	69.1 (68.7-69.6)	68.5 (68.0-69.0)	69.7 (68.9-70.4)	70.6 (69.8-71.3)
60-69 y	1,451 (56.4)	850 (59.8)	278 (53.9)	323 (48.5)
70-79 y	790 (29.2)	470 (29.7)	120 (26.2)	200 (29.4)
80+ y	440 (14.4)	201 (10.4)	86 (19.9)	153 (22.2)
Female	1,379 (54.2)	616 (44.8)	336 (75.8)	427 (68.3)
NH White	1,320 (80.3)	780 (83.3)	171 (64.4)	369 (80.8)
NH Black	629 (8.2)	282 (5.4)	164 (17.9)	183 (10.4)
Mexican American	227 (3.2)	143 (3.2)	54 (6.0)	30 (1.8)
Other Hispanic	260 (3.5)	144 (3.0)	62 (6.6)	54 (3.2)
NH Asian	206 (3.1)	149 (3.3)	30 (4.1)	27 (1.9)
Other / multiracial	39 (1.8)	23 (1.8)	3 (1.0)	13 (2.0)
Foreign-born	609 (10.0)	384 (9.7)	124 (15.7)	101 (7.9)
Tested in Spanish	235 (3.4)	135 (3.2)	71 (7.7)	29 (1.8)
< 9th grade	287 (5.4)	136 (4.2)	94 (13.5)	57 (4.6)
9-11th grade	369 (10.0)	186 (8.3)	77 (14.4)	106 (12.4)
High school / GED	627 (21.8)	343 (20.6)	113 (24.3)	171 (23.7)
Some college / AA	774 (32.0)	458 (33.4)	130 (27.1)	186 (30.6)
College graduate +	624 (30.8)	398 (33.5)	70 (20.8)	156 (28.7)
Income-to-poverty ratio, mean (95% CI)	3.11 (2.96-3.27)	3.50 (3.36-3.65)	2.29 (2.06-2.52)	2.50 (2.27-2.72)
CERAD4, weighted mean (95% CI)	25.98 (25.34-26.60)	26.36 (25.55-27.17)	24.51 (23.47-25.54)	25.71 (25.19-26.23)
Animal Fluency, weighted mean (95% CI)	18.20 (17.81-18.59)	18.63 (18.15-19.12)	16.44 (15.75-17.12)	17.96 (17.29-18.63)
DSST, weighted mean (95% CI)	52.07 (50.92-53.21)	53.79 (52.54-55.03)	45.21 (43.16-47.26)	51.04 (49.00-53.09)

NH = non-Hispanic. Percentages are weighted to the U.S. population using the four-year MEC examination weight and may not sum to 100 because of rounding.

Table 2. Survey-weighted differences in cognitive performance by isolation category

Model	Contrast	Memory (CERAD4)	Processing speed (DSST)	Fluency (Animal)
Unadjusted	Intermediate vs low	-0.290 (-0.459, -0.121)	-0.513 (-0.638, -0.388)	-0.386 (-0.508, -0.263)

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Table 2. (continued)

	High vs low	-0.102 (-0.227, 0.023)	-0.164 (-0.297, -0.031)	-0.119 (-0.259, 0.022)
Model 1: demographic	Intermediate vs low	-0.250 (-0.412, -0.088)	-0.320 (-0.409, -0.230)	-0.171 (-0.295, -0.048)
	High vs low	-0.075 (-0.198, 0.049)	-0.078 (-0.185, 0.030)	0.013 (-0.113, 0.139)
Model 2: + socioeconomic	Intermediate vs low	-0.144 (-0.309, 0.020)	-0.108 (-0.198, -0.018)	-0.050 (-0.174, 0.074)
	High vs low	-0.002 (-0.104, 0.099)	0.063 (-0.031, 0.156)	0.085 (-0.049, 0.219)

Model 1 adjusts for age group, sex, race and Hispanic origin, place of birth, test language, and survey cycle. Model 2 adds education and the family income-to-poverty ratio. All estimates use Taylor-series linearization with SDMVSTRA and SDMVPSU (32 degrees of freedom).

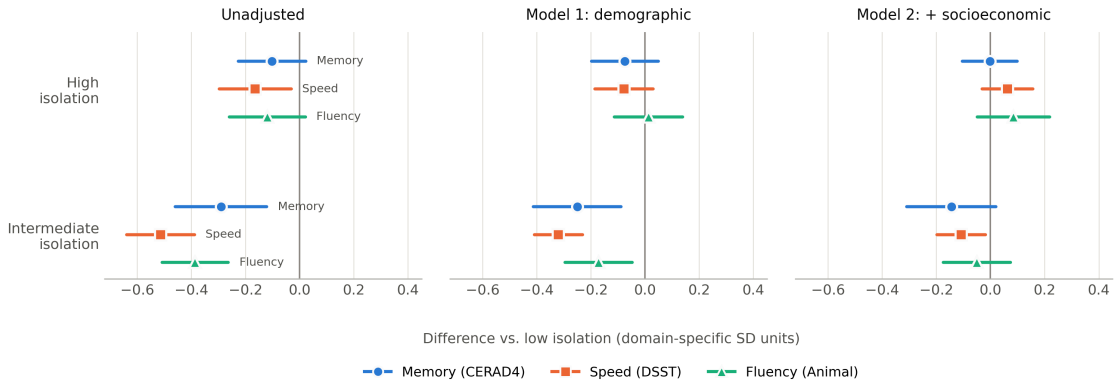


Figure 2. Differences in cognitive performance by isolation category across three models (picture credit: original)

Note: Bars show design-based 95% confidence intervals; the reference group is low isolation.

4. Conclusion

Household-based isolation was associated with cognitive performance in this sample, but not in the ordered way the study expected. The lowest scores in all three domains belonged to the intermediate category, which turned out to be almost entirely unpartnered adults living with other people, while adults who were both unpartnered and living alone scored close to partnered adults in shared households. Most of that gap was explained by age, sex, race and ethnicity, education, and income, and after full adjustment only processing speed retained a difference of about 0.11 standard deviations, roughly 1.8 DSST points. The null hypothesis of equal coefficients across memory, processing speed, and fluency was not rejected in any model, so this study gives no evidence that one of the three domains is more sensitive to household isolation than the others.

A more informative test would need an exposure that records contact frequency, network size, and perceived support rather than household composition alone, since living arrangement here tracked socioeconomic position more closely than it tracked social connection. Longitudinal data

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would also be needed to assess temporal direction because declining cognition can change living arrangements just as social disconnection may influence cognitive health. Measuring depressive symptoms and functional limitation would allow the indirect pathways described in the introduction to be tested rather than assumed. The results should also be interpreted in light of cognitive-component nonresponse and missing socioeconomic data, which may have selected a healthier and more advantaged analytic sample. Accordingly, the estimates describe cross-sectional associations in the sample population, not causal effects or clinical cognitive impairment. Future studies should combine direct measures of social networks with repeated cognitive assessments and broader psychosocial covariates to distinguish household structure from meaningful social disconnection. It is also important to clarify whether particular cognitive domains are differentially affected over time.

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