# *COVID-19 Infections and Cognitive Function*

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**Key Points**

**Question:** Infection with COVID-19 has been associated with subsequent lower cognitive function, but are these findings the result of reverse causality, whereby lower cognitive function increases the probability of infection?

**Findings:** The measures of cognitive function collected in our sample before the pandemic show a significant association with the probability of being infected with COVID-19. Accounting for baseline cognitive function, no evidence is found for a negative effect of a COVID-19 infection on the measures of cognitive function used in the study.

**Meaning:** The results offer no clear evidence that COVID-19 infections are associated with significant deteriorations of the cognitive measures used in the study, suggesting that results reported in the literature may reflect reverse causality, at least for the domains covered by the cognitive measures in the study.

**Abstract**

**Importance:** Long-term health effects of COVID-19 infections are a major public health concern. This study investigates associations between COVID-19 infections and cognitive function.

**Objective:** To determine if COVID-19 infection has a detrimental effect on cognitive function.

**Design:** We use the nationally representative probability-based Understanding America Study (UAS) of approximately 9,600 respondents, which has regularly elicited measures of cognitive function since 2015. Collection of cognition measures took place before and during the pandemic, solely determined by a two-year cycle depending on when respondents joined the study. In addition, between March 10, 2020, and July 20, 2021, 8554 study members have participated in a COVID-19 tracking survey (29 waves total), regularly answering questions about their experiences during the pandemic, including symptoms and whether they have been infected. We tested whether cognitive change differed between respondents who experienced COVID-19 and those who did not.

**Setting:** The UAS is a longitudinal study of U.S. residents who have been recruited from probability-based samples of postal addresses. Respondents answer questions over the Internet once or twice a month. Respondents without prior Internet access have been provided with Internet enabled computer tablets.

**Participants:** U.S. residents 18 years of age or older.

**Exposure:** Self-reported coronavirus infection or diagnosis. COVID-19 risk for the UAS sample was the same as for the general U.S. population.

**Main outcomes:** Six cognitive tests (Numeracy; Number Series, Picture Vocabulary, Verbal Analogies; Serial Sevens; Financial Literacy). Two subjective cognition measures (Self-rated Memory and Memory Change).

**Results:** All six cognitive tests, measured before January 1, 2020, are significant predictors of infection status during the pandemic. The two subjective cognition measures show no significant association with infection. We replicate earlier cross-sectional findings of a negative association between COVID-19 infection and subsequent cognition. However, once accounting for baseline cognition, no significant associations are found for either the tests or the subjective measures. For three of the six cognitive tests the effects change signs.

**Conclusions and relevance:** We find no evidence for a negative association between COVID-19 infection and subsequent measures of cognitive functioning. The associations found in earlier studies may at least partly reflect reverse causation.

## Introduction

There is wide-spread concern about the long-term effects of infection with the SARS-CoV-2 virus[1]. One symptom of concern is what is sometimes referred to as "brain fog" [2], in which COVID-19 survivors complain of feeling mentally slow, fatigued, and unable to concentrate. Others have characterized neurological complications or neurocognitive deficits [3] after recovery from acute COVID-19. Several population based studies find that patients recovering from COVID-19 score lower on a variety of cognitive tests than either some population standard [4-7] or a comparison group of individuals with similar demographic characteristics [8-13], or when controlling for demographic characteristics in multivariate analyses [14]. Studies vary widely in the sizes and selection of samples, and in the severity of infections considered[15].

Most of the studies (with two exceptions, discussed below) are cross-sectional, that is, there is no pre-COVID-19 baseline to which cognition after an infection can be compared. The correlation between infection and subsequent cognitive function may therefore result from reverse causality: those with lower cognitive function may be more likely to get infected [16-19]. Several mechanisms have been proposed for this association, for example, those with lower cognitive function may exhibit less protective behavior such as social distancing[20].

Longitudinal data with pre-pandemic cognitive scores are needed to reduce the risk of reverse causality biasing conclusions about the cognitive effects of COVID-19. Such data are rare. Del Brutto et al. [21] take advantage of a cohort study in rural Ecuador, which collected two waves of cognitive screening pre-pandemic. Among their sample of 93 individuals, 56% had a history of mild symptomatic COVID-19 on average four months prior to the third wave of cognitive screening. They find no difference in pre-pandemic scores for those who did or did not become infected, but a significant adverse effect of COVID-19 infection on subsequent cognitive scores (p=.006). Douaud et al.[22] compare scores on six cognitive tests, on average three years apart, in 785 participants in the UK Biobank study, 401 who tested positive for SARS-CoV-2 in between the two sessions and a matched control sample.[22] Their analyses include 10 scores from the 6 tests. After correcting for the Familywise Error Rate (FWER), they find that the times taken to complete two TrailMaking tests (numeric and alphanumeric) increase significantly more for those who had tested positive for SARS-CoV-2 ($p_{fwe}$=.03, and $p_{fwe}$=.002, respectively).

The present study aims to investigate two hypotheses: (1) Lower cognitive scores are associated with a higher likelihood of getting COVID-19 disease; (2) COVID-19 disease is associated with a decline in cognitive scores.

## Methods

### Study Population

The Understanding America Study (UAS, USC Institutional Review Board approval: UP-14-00148) is a probability-based Internet panel of U.S. residents, founded in 2014 and currently comprising about 9,600 respondents 18 years or older. Respondents are recruited by Address Based Sampling and provided with broadband Internet and a computer tablet if needed. They answer brief questionnaires (30 minutes or less) once or twice a month, for which they are compensated at a rate of $20 per thirty minutes of survey time. A large core (about four hours-worth of survey time) is repeated every two years and includes the complete Health and Retirement Study[23-25] (HRS) core questionnaire and several cognitive tests. Since respondents enter the study at different times (the study is still growing), their biennial answers to the core questions are elicited at different time points.

In addition to the core questions, repeated every two years, respondents are invited to answer other surveys. Between March 10, 2020, and April 1, 2020, UAS respondents answered a survey related to the emerging COVID-19 pandemic, including questions about work and income, protective behaviors, symptoms, use of and trust in various information sources. They were also asked if they had been tested for the coronavirus, and if so, the result. In addition, they were asked, regardless of the test, whether a doctor or healthcare professional diagnosed them as having or probably having the coronavirus. We define a respondent who answered having tested positive or who reported to have been diagnosed as having the COVID-19 virus as being infected[26]. Starting March 29, 2020, UAS respondents were invited to participate in bi-weekly COVID-19 "tracking surveys" starting on April 1,2020, with similar content as the March survey. The tracking surveys were approved by the USC IRB (UP-14-00148-AM088). In total, 29 bi-weekly (every four weeks after February 17, 2021) surveys were administered through June 2021.

While participating in the tracking surveys, respondents also kept answering core surveys according to the two-year schedule determined by when they joined the study. Thus, our data comprise both information on incidence and timing of self-reported COVID-19 infections and various cognition measures elicited before, during, or after respondents answered tracking surveys.

### Cognition Measures

The following measures of cognitive function are considered.

1. Numeracy (Numeracy). Respondents are asked to solve 8 problems designed to measure "the ability to understand, manipulate, and use numerical information, including probabilities"[27]. Scores are derived using a 2-parameter item-response theory (IRT) model (normed with mean = 50, SD = 10 in the general population).
2. Woodcock Johnson Number Series (WJ Numbers) [28]. This quantitative reasoning test presents respondents with a series of numbers with one number missing. They need to determine the numerical pattern and provide the missing number. Two parallel forms (15 items each) are rotated

across biennial assessments to reduce practice effects (2-parameter IRT scores normed at mean = 50, SD = 10).

3. Woodcock Johnson Picture Vocabulary (WJ Picture Vocabulary). This verbal ability test requires naming familiar to less familiar pictures[28]. Two 15-item parallel forms are rotated (2-parameter IRT scores, mean = 50, SD = 10).
4. Woodcock Johnson Verbal Analogies (WJ Verbal Analogies). In this verbal reasoning test, respondents need to recognize a relationship between two words and apply it to two other words[28]. Two 15-item parallel forms are rotated (2-parameter IRT scores, mean = 50, SD = 10).
5. Serial Sevens (Serial Sevens). This working memory and mental processing task asks respondents, starting at 100, to repeatedly subtract seven for a total of five trials[29]. The score runs from 0 (none correct) to 5 (five consecutive subtractions correct).
6. Financial Literacy (Financial Literacy). Respondents answer 14 multiple choice questions testing their knowledge of financial matters [30-32]. Their score is the total number of items answered correctly.

In addition to these six cognitive tests, we consider the following two subjective cognition measures, which are part of the HRS core questionnaire.

7. Self-rated memory (Self-rated Memory). Respondents rate their memory as Excellent (5), Very good (4), Good (3), Fair (2), Poor (1).
8. Self-rated change in memory (Memory Change). Respondents compare their memory with two years ago and rate the change as Better (3), Same (2), or Worse (1).

The cognitive tests and subjective cognition measures will be jointly referred to as "cognition measures". Serial Sevens, Self-rated Memory, and Memory Change are all part of the HRS survey instrument and have been elicited in up to four waves. All other measures have been elicited at most three times.

**Other Measures**

Demographic information, including sex, age, race/ethnicity, education, household income, marital status, and working status, are collected quarterly as part of the regular UAS interview schedule.

**Statistical Analysis**

Due to the biennial survey frequency, only the most recently obtained cognition measure could possibly have been elicited after an infection. For each cognition measure, we test whether changes up to and including the penultimate wave are the same for respondents who get infected later and those who don't (the "Common trends" assumption[33]). The tests are performed by regressing the cognitive measures on wave dummies and interactions of these dummies with an indicator whether an individual got infected at any time before the end of our observation period (July 1, 2021).

If an infection has a negative effect on cognition, we expect the change between the penultimate and final wave to be different between those who got infected and those who did not. We therefore also test the "No break" hypothesis that changes between the penultimate and last wave are the same for infected and non-infected. This is similar to the common trends test, but now the distinction is whether a measure has been elicited after an infection.

The core of our analysis consists of three regressions applied to each of the eight measures: (1) The most recent cognition measures obtained before January 1, 2020, and a set of demographics are included in logistic regressions predicting the likelihood that one reports infection any time after that; (2) The most recent cognition measure by domain is regressed by Ordinary Least Squares (OLS) on demographics and an indicator of prior infection; (3) Fixed Effects (FE) regressions with robust standard errors, using all waves of cognitive tests, are used to explain the measures by age at the time of test taking[1] and by the indicator of prior infection. Fixed effects are individual intercepts in a regression, and hence control for any time-invariant omitted variables that may affect the probability of infection. This is essential when the goal is to obtain evidence of a causal connection from observational data[34 35]. Both the OLS and FE regressions include indicators for how often respondents have taken the tests, to control for learning effects.

Potentially, an infection may induce a respondent to stop responding to the tracking surveys, or to later cognitive tests, which will attenuate any estimated effect of an infection on cognition, as we would be selectively missing cognitive tests from infected respondents. Thus, we test whether response rates to the tracking surveys fall after an infection.

All analyses presented in this paper have been conducted with Stata version 16.0.

## Results

Figure 1 shows the number of respondents to each pandemic survey as well as response rates. The initial March survey was offered to all UAS respondents and yielded 6,932 responses (80.5% response rate). The basis for calculating the response rate for the subsequent tracking surveys, is the number of respondents who consented to participation in those surveys. As many respondents consented after April 1 and new respondents joined the panel, the number of respondents available for each tracking survey grew over time. Simultaneously the response rate to the tracking surveys trended downward. This resulted in an almost constant number of responses to each survey, with a response rate declining from 97.3% to the first survey (April 1-April 14, 2020) to 70.0% to the last survey fielded on June 9, 2021. Overall, out of 9,111 respondents answering the consent survey for the tracking surveys, 8,847 (97.1%) consented to participate, among whom, 8,628 (97.5%) answered at least one tracking survey.

Table 1 presents the demographic composition of the sample, broken down by whether a respondent has reported an infection at any time during the period March 10, 2020-July 1, 2021. Out of 8,628 respondents who have participated in at least one tracking survey, 8,554 (99.1%) have cognitive scores and demographic information. This includes 1058 respondents out of a total of 1,061 (12.7%) respondents who report having been infected. The latest cognition measures were elicited on October 19, 2021. In a follow-up survey conducted between September 23 and October 31, 2021, we asked respondents whether they had been infected since the last tracking survey they answered. Since we do not know if the infection occurred before or after the last cognitive measure was taken, we have excluded the cognitive tests of individuals who reported being infected in this survey (207 cases). This results in our analytic sample of 8,554 respondents.

On average we have 2.19 observations per cognition measure per non-infected respondent and 2.27 for infected respondents. Table 1 shows that compared to the non-infected, the infected are more likely to

[1] The remaining demographics are not time varying and hence get absorbed in the individual fixed effects.

have a lower education and lower household income. They are more likely to be Hispanic, to be working, and are approximately 2.5 years younger.

The bottom panel of the table shows mean scores for the six cognitive tests and two subjective cognition measures, as well as response rates. The overall means for Numeracy and the WJ tests are somewhat above the population mean of 50, while the standard deviations are below the population standard deviation of 10.  For all tests, infected respondents show lower scores than non-infected.

Figure 2 shows the distribution of times elapsed between the reported COVID-19 infection and the cognition measures elicited after the infection. Since Serial Sevens, Self-rated Memory, and Memory Change are always elicited in the same HRS survey, the durations are identical for these measures. Similarly, Financial Literacy and Numeracy are always measured in the same survey. Figure 2 shows that infections that occurred longer ago are less frequent than more recent infections, reflecting the gradual increase in reported infections over time.

Figure 3 shows average cognitive scores by wave and by whether a respondent has been infected before the last wave. As the UAS keeps growing, earlier waves have lower numbers of observations than later waves, and confidence intervals are correspondingly larger. As waves are two years apart, only the last wave of each measure can be after a possible infection.

The null hypothesis of common trends before the pandemic gets accepted for all tests, but not for Self-rated Memory. It improves sharply before the pandemic for respondents who later get infected and falls after infection, while for the non-infected Self-rated Memory is essentially constant. This also results in the only statistically significant break associated with infection. However, after correction for FWER using Holm's method[36] the break loses statistical significance.

Table 2 summarizes the regression estimates, adjusted for demographics listed in Table 1 and dummies indicating how often a respondent has taken a test. Supplemental tables A1 and A2 present complete results. The columns in Table 2 represent independent variables in the regressions, while the rows represent the dependent variables.

The column "Cognitive score before 2020" shows that all test scores (but not the subjective measures) before January 1, 2020, significantly predict infection risk during the pandemic. As Numeracy and the three Woodcock Johnson measures have a population standard deviation equal to 10, raising the odds ratios to the power 10 shows that a one standard deviation increase in these tests is associated with a reduction in the infection probability by 14-19%. Similarly, getting one additional serial seven subtraction correct is associated with a lower infection probability by about 8%, while a one standard deviation increase in financial literacy is associated with a reduced probability of infection by about 13%.

The column "Effect of infection on cognitive score" shows associations between infections and subsequent cognitive scores, estimated by either OLS or FE. The OLS results use only the last available cognition measure and thus mimic results if only cross-sectional data were available.

The OLS regressions all show the cognition measures are consistently lower for those who reported being infected. The effects are statistically significant for WJ Picture Vocabulary and WJ Verbal Analogies, also after correction for FWER.

The FE regressions use all waves of the cognitive measures, accounting for the pre-pandemic differences. Compared to the OLS results, the effects of a prior COVID-19 infection become much smaller and in three cases (Numeracy, WJ Numbers, Serial Sevens) switch sign. After correction for FWER no effect is significantly different from zero at the .05 significance level.

Supplemental tables A1 and A2 show effects of respondent background characteristics. Older people have a lower risk of infection. The same holds for individuals with a college degree, males and never-married. Working individuals and Hispanics show a substantially elevated infection risk. In the FE regressions, most measures of cognitive function show a negative or insignificant relation with age, except WJ Numbers which shows a significantly positive association.

Potentially, cognitive effects of a COVID-19 infection may change over time. Supplemental tables A3 and A4 repeat the analyses shown in tables A1 and A2 but add time since infection as an additional variable in the cross-sectional and FE regressions. This variable is never statistically significant.

Supplemental Table A5 shows that response rates to the tracking are slightly lower immediately after a COVID-19 infection. The effect is marginally significant (p=.06) in the second tracking wave after an infection and disappears in waves after that.

## Discussion

A strength of our analysis lies in the large nationally representative longitudinal survey data, and the availability of cognition measures elicited according to a fixed biennial schedule. The self-reports of COVID-19 infections since early March 2020 have allowed us to compare changes in cognition between respondents who did and who did not report COVID-19 infections and thus to address the potential effect of reverse causality. The use of FE estimation moreover addresses the possibility of unobserved time-invariant confounding factors. We establish a significant effect of prior cognitive function on the likelihood of infection and replicate the finding in the literature of a significantly negative association of a COVID-19 infection with cognitive function in cross-sectional analyses. However, once prior cognitive tests are accounted for in the FE regressions, we find no effect of COVID-19 on post-infection cognition.

An important limitation of our study is that the cognitive measures for which the UAS has longitudinal data do not tap into all possible domains that may have been affected. The TrailMaking test scores that were found to be affected by COVID-19 infections by Douaud et al.[22] have no counterpart in the tests available in this study. Similarly, the Montreal Cognitive Assessment (MoCA) used by Del Brutto et al.[21]overlaps only partly with the domains considered in our study.

Another possible weakness is that COVID-19 infections are self-reported, and the potential underreporting may attenuate estimated effects of infection on subsequent cognition. However, the fact that our observed infection rate was similar to that in the general U.S. population and the infection was predicted by pre-2020 cognition measures, as suggested by the literature, supports the validity of the self-report infection.

**Conclusions**

Using a nationally representative panel, we find lower pre-pandemic cognition predicts increased risk of the COVID-19 infection, but no negative association between infection and subsequent cognitive functioning, after accounting for possible reverse causality.

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Figure 1:Total response and response rates by wave

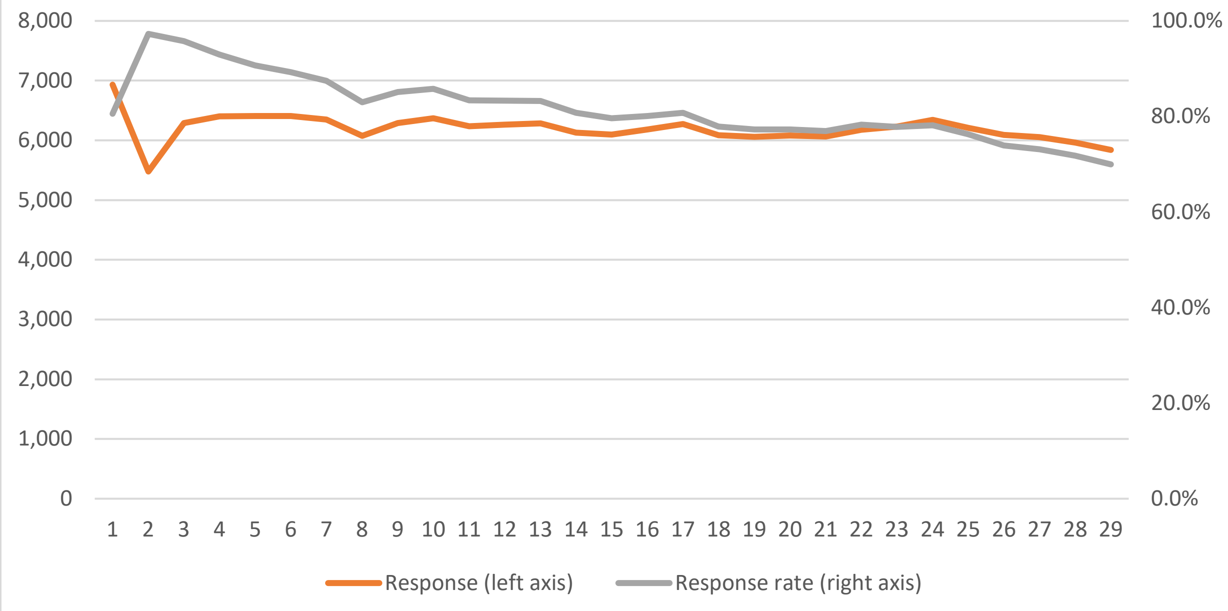



Figure 2: Elapsed time between infection and test taken

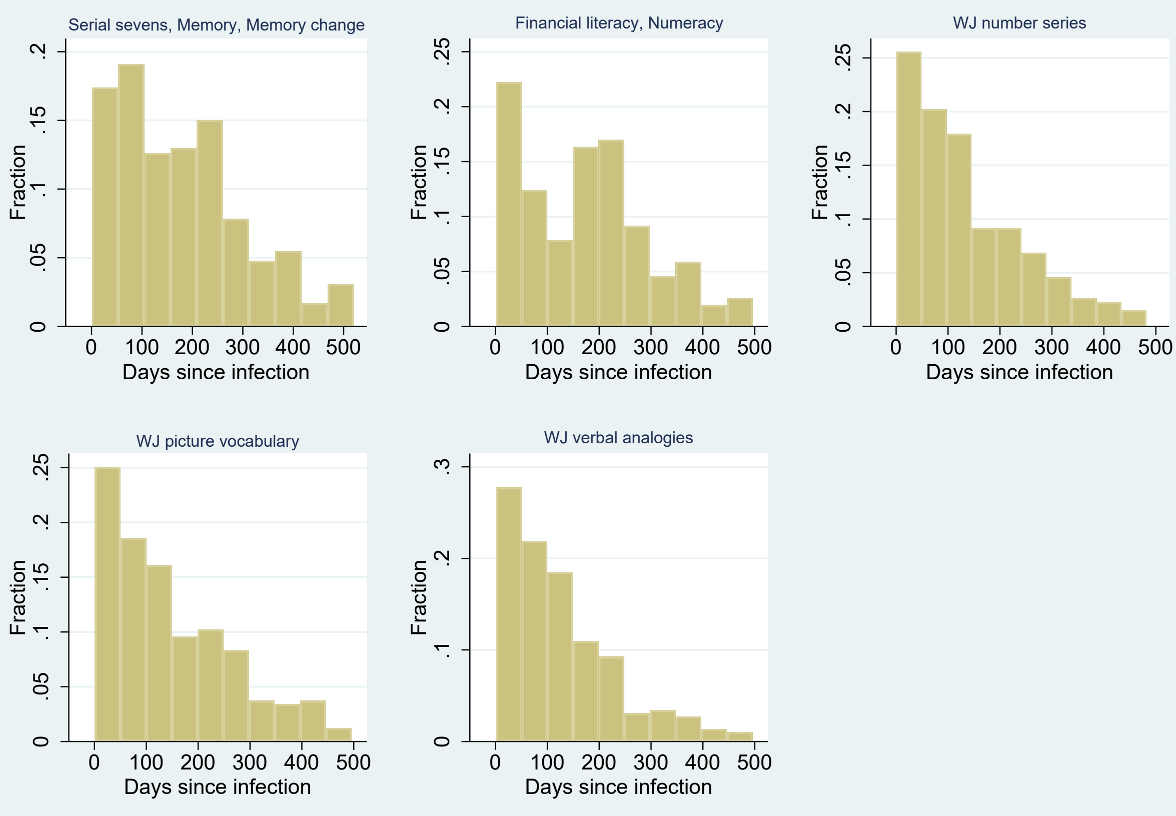
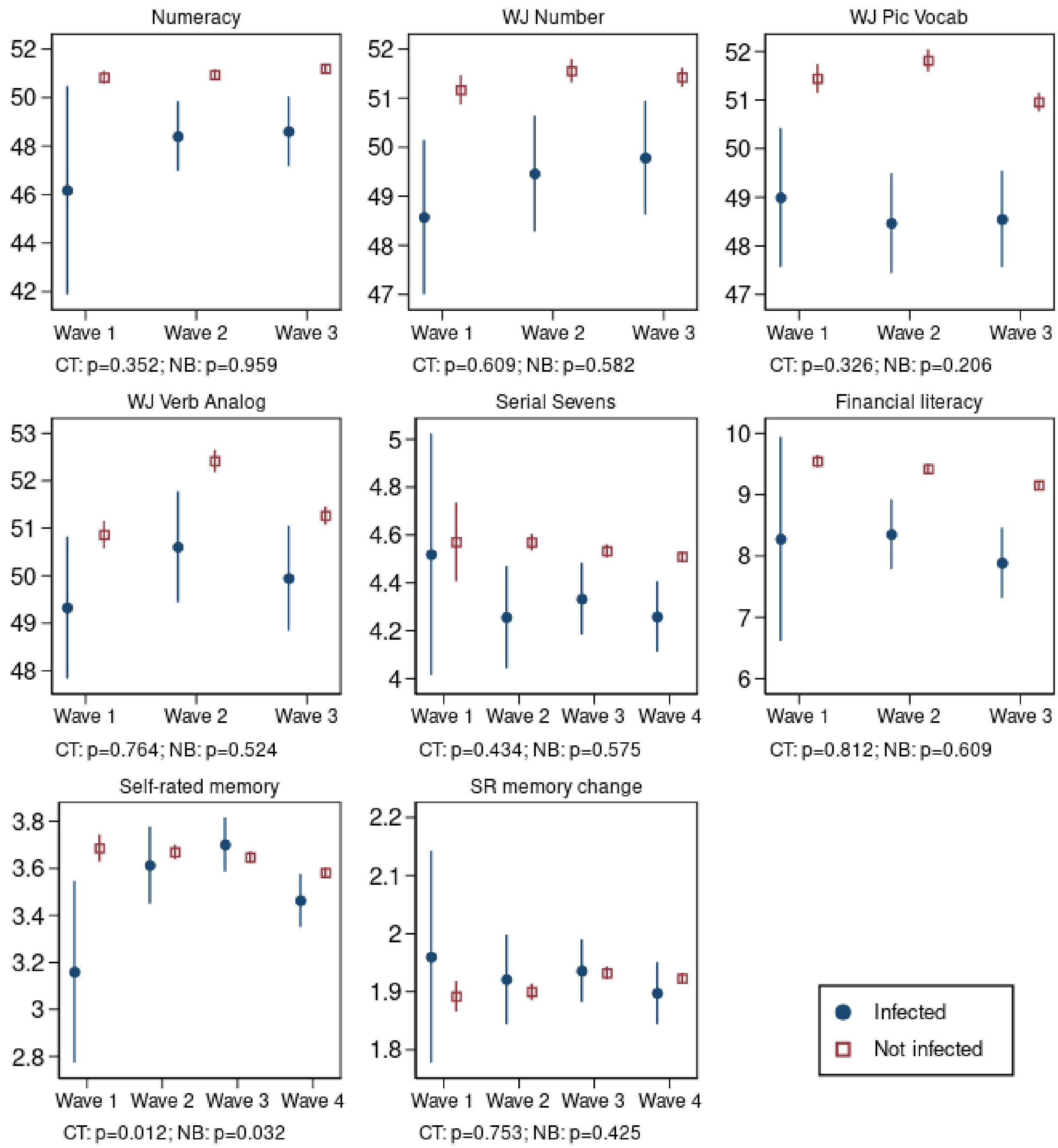


**Figure 3: Changes in cognition measures**




Note. CT: test for common trend; NB: test for no break

| Table 1: Composition of Analytic Sample | | | | | |
|---|---|---|---|---|---|
| | | Full Sample (N=8554) | Infected (N=1058) | Not Infected (N=7496) | p |
| Education, n (%) | | | | | <.0001 |
| | High school or less | 1930 (22.6) | 277 (26.2) | 1653 (22.1) | |
| | Some College | 3187 (37.3) | 442 (41.8) | 2745 (36.6) | |
| | Bachelor's or more | 3436 (40.2) | 338 (32.0) | 3098 (41.3) | |
| Household income, n (%) | | | | | 0.007 |
| | Household income: 0-29,999 | 2248 (26.3) | 290 (27.4) | 1958 (26.2) | |
| | Household income: 30,000-59,999 | 2267 (26.6) | 312 (29.5) | 1955 (26.1) | |
| | Household income: 60,000-99,999 | 2077 (24.3) | 254 (24.0) | 1823 (24.4) | |
| | Household income: 100,000 or more | 1944 (22.8) | 201 (19.0) | 1743 (23.3) | |
| Sex, n (%) | | | | | <.0001 |
| | Male | 3499 (40.9) | 366 (34.6) | 3133 (41.8) | |
| Marital status, n (%) | | | | | 0.34 |
| | Married | 4607 (53.9) | 589 (55.7) | 4018 (53.6) | |
| | Sep/Div/Wid | 1674 (19.6) | 206 (19.5) | 1468 (19.6) | |
| | Never Married | 2269 (26.5) | 262 (24.8) | 2007 (26.8) | |
| Race/Ethnicity, n (%) | | | | | <.0001 |
| | White | 5512 (64.5) | 638 (60.5) | 4874 (65.1) | |
| | Black | 728 (8.5) | 82 (7.8) | 646 (8.6) | |
| | Other, non-Hispanic | 868 (10.2) | 93 (8.8) | 775 (10.3) | |
| | Hispanic | 1435 (16.8) | 242 (22.9) | 1193 (15.9) | |
| Currently working, n (%) | | | | | 0.03 |
| | Yes | 5250 (61.4) | 681 (64.4) | 4571 (61.0) | |
| Age at test taking, mean (SD) | | | | | |
| | HRS measures[a] | 49.4 (15.8) | 47.2 (14.7) | 49.8 (16.0) | <.0001 |
| | Financial Literacy/Numeracy | 49.2 (15.9) | 46.9 (14.7) | 49.5 (16.0) | <.0001 |
| | WJ Numbers | 49.6 (15.8) | 47.2 (14.6) | 49.9 (16.0) | <.0001 |
| | WJ Picture Vocabulary | 49.5 (15.9) | 47.2 (14.6) | 49.9 (16.0) | <.0001 |
| | WJ Verbal Analogies | 49.7 (15.8) | 47.3 (14.6) | 50.0 (16.0) | <.0001 |
| Cognitive scores[b], mean (SD) | | | | | |
| | Numeracy (96.1, 88.9, 97.0) | 51.0 (8.9) | 49.1 (8.6) | 51.3 (8.9) | <.0001 |
| | WJ Numbers (87.8, 89.7, 91.9) | 51.3 (9.1) | 49.6 (9.2) | 51.6 (9.1) | <.0001 |
| | WJ Picture Vocabulary (97.4, 90.9, 92.9) | 51.2 (9.0) | 49.6 (8.8) | 51.5 (9.0) | <.0001 |
| | WJ Verbal Analogies (98.1, 90.9, 90.9) | 51.5 (8.8) | 50.3 (9.2) | 51.7 (8.7) | <.0001 |
| | Serial Sevens (99.1, 99.9, 99.6, 73.3) | 4.5 (1.1) | 4.4 (1.2) | 4.5 (1.0) | <.0001 |
| | Financial Literacy (96.1, 88.9, 97.0) | 9.3 (3.4) | 8.6 (3.3) | 9.4 (3.4) | <.0001 |
| | Self-rated Memory (99.1, 99.9, 99.6, 73.3) | 3.6 (0.9) | 3.6 (1.0) | 3.6 (0.9) | 0.048 |
| | Memory Change (99.1, 99.9, 99.6, 73.3) | 1.9 (0.4) | 1.9 (0.4) | 1.9 (0.4) | 0.154 |

[a]HRS measures: cognitive measures from the Health and Retirement Study (HRS), including Serial Sevens, self-rated memory, and memory change.

[b]Numbers in parentheses indicate response rates by survey administration. Cognition has been elicited in either 3 or 4 waves. Since the UAS has grown over time, many respondents have joined after earlier waves were closed. The field periods for the final waves have not ended yet, which explains lower response rates in several cases.

N indicates the total number of cognitive measures elicited across all survey administrations.

P-values refer to t-tests or to Chi squared tests as appropriate.

**Table 2: COVID-19 infections and cognitive scores for eight measures**

| Cognitive Measure | Estimation Method[a] | Dependent Variable | Cognitive score before 2020 | Standard Error | Effect of infection on cognitive score | Standard Error | Observations | R-squared | Pseudo R-squared |
|---|---|---|---|---|---|---|---|---|---|
| **Numeracy** | Logit | Got infected? | 0.9795 | [0.0047]*** | | | 7126 | | 0.021 |
| | OLS | Numeracy | | | -0.8864 | [0.6163] | 8563 | 0.325 | |
| | FE | Numeracy | | | 0.2321 | [0.4953] | 19063 | 0.000 | |
| **WJ numbers** | Logit | Got infected? | 0.9792 | [0.0046]*** | | | 6885 | | 0.021 |
| | OLS | WJ numbers | | | -0.8113 | [0.5106] | 8516 | 0.261 | |
| | FE | WJ numbers | | | 0.0729 | [0.3843] | 18110 | 0.007 | |
| **WJ Picture Vocabulary** | Logit | Got infected? | 0.9848 | [0.0049]*** | | | 6702 | | 0.019 |
| | OLS | WJ Picture Vocabulary | | | -1.7714 | [0.4231]*** | 8393 | 0.354 | |
| | FE | WJ Picture Vocabulary | | | -0.6188 | [0.3221]* | 18202 | 0.044 | |
| **WJ Verbal Analogies** | Logit | Got infected? | 0.9855 | [0.0045]*** | | | 6583 | | 0.020 |
| | OLS | WJ Verbal Analogies | | | -1.4719 | [0.4617]*** | 8340 | 0.242 | |
| | FE | WJ Verbal Analogies | | | -0.6679 | [0.4180] | 17629 | 0.086 | |
| **Serial Sevens** | Logit | Got infected? | 0.9242 | [0.0300]** | | | 6823 | | 0.019 |
| | OLS | Serial sevens | | | -0.0768 | [0.0631] | 8499 | 0.084 | |
| | FE | serial sevens | | | 0.0471 | [0.0788] | 18433 | 0.008 | |
| **Financial Literacy** | Logit | Got infected? | 0.9606 | [0.0131]*** | | | 7123 | | 0.020 |
| | OLS | Financial literacy | | | -0.4850 | [0.2192]** | 8563 | 0.420 | |
| | FE | Financial Literacy | | | -0.1620 | [0.2005] | 19090 | 0.014 | |
| **Self-rated Memory** | Logit | Got infected? | 1.0115 | [0.0394] | | | 6823 | | 0.017 |
| | OLS | Self-rated Memory | | | -0.0678 | [0.0558] | 7079 | 0.055 | |
| | FE | Self-rated memory | | | -0.0965 | [0.0553]* | 18454 | 0.007 | |
| **Memory Change** | Logit | Got infected? | 0.9890 | [0.0095] | | | 6824 | | 0.013 |
| | OLS | Memory Change | | | -0.0216 | [0.0278] | 7081 | 0.014 | |
| | FE | Memory Change | | | -0.0439 | [0.0296] | 18453 | 0.010 | |

The table shows effects of the variables in column headers on the measures listed in the rows. All models are fully saturated with the background variables listed in Table 1. Supplemental tables A1 and A2 show the full results.

Standard errors in brackets * p<0.10 ** p<0.05 *** p<0.01"

[a] Logit: Logistic Regression; OLS: Ordinary Least Squares; FE: Fixed Effects

Supplemental tables

**Table A1: COViD-19 infections and scores for Numeracy, Numbers, Picture Vocabulary, and Verbal Analogies**

| | Logit | OLS | FE | Logit | OLS | FE | Logit | OLS | FE | Logit | OLS | FE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Had covid?** | **Numeracy** | **Numeracy** | **Had covid?** | **WJ numbers** | **WJ numbers** | **Had covid?** | **WJ Picture Vocabulary** | **WJ Picture Vocabulary** | **Had covid?** | **WJ Verbal Analogies** | **WJ Verbal Analogies** |
| Age | 0.9886 | -0.0561 | -0.0318 | 0.9902 | -0.0480 | 0.1576 | 0.9929 | 0.1648 | 0.0484 | 0.9893 | -0.0659 | -0.0317 |
| | [0.0028]*** | [0.0062]*** | [0.0323] | [0.0029]*** | [0.0068]*** | [0.0484]*** | [0.0031]** | [0.0062]*** | [0.0424] | [0.0030]*** | [0.0065]*** | [0.0431] |
| Currently working | 1.0758 | -0.1245 | | 1.1490 | -0.2267 | | 1.1361 | -0.4021 | | 1.1242 | 0.1554 | |
| | [0.0890] | [0.1854] | | [0.0974] | [0.2019] | | [0.0978] | [0.1850]** | | [0.0976] | [0.1938] | |
| Some College | 1.0676 | 2.7497 | | 1.0554 | 3.0700 | | 1.0391 | 2.9001 | | 1.0397 | 3.0382 | |
| | [0.0982] | [0.2196]*** | | [0.0989] | [0.2386]*** | | [0.0986] | [0.2188]*** | | [0.0991] | [0.2293]*** | |
| Bachelor's or more | 0.7921 | 6.9131 | | 0.7556 | 6.5663 | | 0.6991 | 4.0330 | | 0.7143 | 5.2969 | |
| | [0.0862]** | [0.2335]*** | | [0.0831]** | [0.2541]*** | | [0.0765]*** | [0.2329]*** | | [0.0798]*** | [0.2438]*** | |
| 30000-59999 | 1.0892 | 2.2733 | | 1.1237 | 2.4175 | | 1.0914 | 1.6807 | | 1.1123 | 2.6554 | |
| | [0.1102] | [0.2374]*** | | [0.1176] | [0.2577]*** | | [0.1155] | [0.2367]*** | | [0.1187] | [0.2473]*** | |
| 60000-99999 | 1.0416 | 3.5418 | | 1.1487 | 3.7886 | | 1.0684 | 2.5637 | | 1.0585 | 3.4651 | |
| | [0.1179] | [0.2546]*** | | [0.1328] | [0.2759]*** | | [0.1248] | [0.2537]*** | | [0.1252] | [0.2651]*** | |
| 100000 or more | 0.9791 | 4.9330 | | 1.0688 | 4.7206 | | 1.0264 | 3.4131 | | 1.0647 | 4.3301 | |
| | [0.1239] | [0.2721]*** | | [0.1373] | [0.2959]*** | | [0.1318] | [0.2709]*** | | [0.1382] | [0.2837]*** | |
| male | 0.8496 | 3.7517 | | 0.8220 | 2.9189 | | 0.7911 | 1.3841 | | 0.7778 | 0.3480 | |
| | [0.0666]** | [0.1678]*** | | [0.0647]** | [0.1827]*** | | [0.0628]*** | [0.1668]*** | | [0.0618]*** | [0.1750]** | |
| Separated/Divorced/Widowe | 0.9472 | -0.0533 | | 0.9452 | -0.1972 | | 0.9767 | -0.2226 | | 0.9949 | 0.2018 | |
| | [0.0933] | [0.2221] | | [0.0945] | [0.2415] | | [0.0985] | [0.2203] | | [0.1006] | [0.2311] | |
| Never Married | 0.6261 | 0.6950 | | 0.6487 | 0.5171 | | 0.6549 | 0.1215 | | 0.6477 | 0.1407 | |
| | [0.0642]*** | [0.2223]*** | | [0.0675]*** | [0.2429]** | | [0.0693]*** | [0.2225] | | [0.0694]*** | [0.2340] | |
| Black | 0.9091 | -5.4610 | | 0.9242 | -5.6953 | | 0.8967 | -7.4400 | | 0.9178 | -7.0003 | |
| | [0.1280] | [0.3026]*** | | [0.1318] | [0.3289]*** | | [0.1315] | [0.2985]*** | | [0.1342] | [0.3133]*** | |
| Other non-Hispanic | 0.9909 | 0.3491 | | 0.9976 | -0.4812 | | 0.9349 | -4.6427 | | 0.9830 | -2.3827 | |
| | [0.1279] | [0.2734] | | [0.1311] | [0.2989] | | [0.1256] | [0.2717]*** | | [0.1314] | [0.2847]*** | |
| Hispanic | 1.2728 | -3.5518 | | 1.2841 | -3.5630 | | 1.2405 | -5.0363 | | 1.2704 | -4.5013 | |
| | [0.1217]** | [0.2339]*** | | [0.1267]** | [0.2575]*** | | [0.1303]** | [0.2401]*** | | [0.1337]** | [0.2523]*** | |
| Cog. score before 2020 | 0.9795 | | | 0.9792 | | | 0.9848 | | | 0.9855 | | |
| | [0.0047]*** | | | [0.0046]*** | | | [0.0049]*** | | | [0.0045]*** | | |
| After infection | | -0.8864 | 0.2321 | | -0.8113 | 0.0729 | | -1.7714 | -0.6188 | | -1.4719 | -0.6679 |
| | | [0.6163] | [0.4953] | | [0.5106] | [0.3843] | | [0.4231]*** | [0.3221]* | | [0.4617]*** | [0.4180] |
| Second test | | -0.3247 | 0.0710 | | 0.1169 | 0.2485 | | 1.7605 | 1.6156 | | 2.9243 | 2.7359 |
| | | [1.5919] | [0.1117] | | [0.2410] | [0.1324]* | | [0.2166]*** | [0.1214]*** | | [0.2319]*** | [0.1300]*** |
| Third test | | -0.6837 | 0.2559 | | 0.7069 | -0.0046 | | 1.4670 | 0.9079 | | 1.4972 | 0.9003 |
| | | [1.5837] | [0.1617] | | [0.2132]*** | [0.2242] | | [0.2000]*** | [0.1957]*** | | [0.2033]*** | [0.2059]*** |
| Constant | 0.8019 | 47.4074 | 52.4298 | 0.7151 | 46.8718 | 43.4517 | 0.5208 | 38.5812 | 48.1102 | 0.5981 | 48.5723 | 52.0193 |
| | [0.2278] | [1.6321]*** | [1.5157]*** | [0.2051] | [0.4771]*** | [2.3260]*** | [0.1419]** | [0.4396]*** | [2.0355]*** | [0.1763]* | [0.4587]*** | [2.0800]*** |
| Observations | 7126 | 8563 | 19063 | 6885 | 8516 | 18110 | 6702 | 8393 | 18202 | 6583 | 8340 | 17629 |
| R-squared | | 0.325 | 0.000 | | 0.261 | 0.007 | | 0.354 | 0.044 | | 0.242 | 0.086 |
| Pseudo R-squared | 0.021 | | | 0.021 | | | 0.019 | | | 0.020 | | |
| Standard errors in brackets | * p<0.10 | ** p<0.05 | *** p<0.01" | | | | | | | | | |

| Table A2: COViD-19 infections and scores for Serial sevens, self-rated memory (and change), Financial literacy | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Logit | OLS | FE | Logit | OLS | FE | Logit | OLS | FE | Logit | OLS | FE |
| | **Had covid?** | **Serial sevens** | **serial sevens** | **Had covid?** | **Financial literacy** | **Financial Literacy** | **Had covid?** | **Self-rated Memory** | **Self-rated memory** | **Had covid?** | **Memory Change** | **Memory Change** |
| Age | 0.9908 | -0.0007 | -0.0118 | 0.9915 | 0.0427 | 0.0155 | 0.9908 | -0.0029 | -0.0080 | 0.9990 | -0.0016 | -0.0000 |
| | [0.0029]*** | [0.0009] | [0.0087] | [0.0029]*** | [0.0022]*** | [0.0161] | [0.0029]*** | [0.0008]*** | [0.0049] | [0.0003]*** | [0.0004]*** | [0.0035] |
| Currently working | 1.1439 | 0.0395 | | 1.0917 | 0.1119 | | 1.1358 | 0.1150 | | 1.0138 | 0.0244 | |
| | [0.0975] | [0.0261] | | [0.0905] | [0.0662]* | | [0.0967] | [0.0249]*** | | [0.0096] | [0.0122]** | |
| Some College | 1.0279 | 0.2690 | | 1.0630 | 1.2353 | | 1.0100 | 0.1251 | | 1.0019 | -0.0097 | |
| | [0.0959] | [0.0308]*** | | [0.0984] | [0.0784]*** | | [0.0940] | [0.0293]*** | | [0.0115] | [0.0139] | |
| Bachelor's or more | 0.6889 | 0.3832 | | 0.7648 | 2.7963 | | 0.6703 | 0.2353 | | 0.9598 | -0.0049 | |
| | [0.0741]*** | [0.0328]*** | | [0.0843]** | [0.0833]*** | | [0.0719]*** | [0.0313]*** | | [0.0115]*** | [0.0147] | |
| 30000-59999 | 1.1438 | 0.3160 | | 1.0875 | 1.0883 | | 1.1107 | 0.1129 | | 1.0126 | 0.0149 | |
| | [0.1195] | [0.0332]*** | | [0.1106] | [0.0847]*** | | [0.1151] | [0.0317]*** | | [0.0120] | [0.0159] | |
| 60000-99999 | 1.0634 | 0.3419 | | 1.0379 | 1.8041 | | 1.0276 | 0.1892 | | 1.0035 | -0.0163 | |
| | [0.1239] | [0.0358]*** | | [0.1190] | [0.0909]*** | | [0.1190] | [0.0341]*** | | [0.0130] | [0.0167] | |
| 100000 or more | 1.0005 | 0.3979 | | 0.9737 | 2.4126 | | 0.9627 | 0.2763 | | 0.9961 | -0.0071 | |
| | [0.1282] | [0.0381]*** | | [0.1248] | [0.0971]*** | | [0.1227] | [0.0361]*** | | [0.0137] | [0.0175] | |
| male | 0.7905 | 0.0627 | | 0.8191 | 1.1017 | | 0.7860 | 0.0505 | | 0.9753 | 0.0415 | |
| | [0.0618]*** | [0.0236]*** | | [0.0637]** | [0.0599]*** | | [0.0615]*** | [0.0225]** | | [0.0081]*** | [0.0104]*** | |
| Separated/Divorced/Widowed | 1.0035 | 0.0438 | | 0.9496 | -0.0908 | | 0.9975 | -0.1011 | | 0.9989 | -0.0138 | |
| | [0.1001] | [0.0312] | | [0.0935] | [0.0793] | | [0.0994] | [0.0299]*** | | [0.0112] | [0.0141] | |
| Never Married | 0.6749 | 0.0251 | | 0.6206 | 0.1300 | | 0.6731 | -0.0278 | | 0.9582 | -0.0257 | |
| | [0.0703]*** | [0.0313] | | [0.0635]*** | [0.0793] | | [0.0701]*** | [0.0296] | | [0.0110]*** | [0.0144]* | |
| Black | 1.0024 | -0.2595 | | 0.9407 | -1.8327 | | 1.0328 | 0.0472 | | 1.0045 | 0.0987 | |
| | [0.1407] | [0.0424]*** | | [0.1323] | [0.1080]*** | | [0.1442] | [0.0399] | | [0.0153] | [0.0196]*** | |
| Other non-Hispanic | 1.0150 | -0.1168 | | 0.9839 | -0.2237 | | 1.0228 | -0.1736 | | 1.0017 | -0.0032 | |
| | [0.1334] | [0.0386]*** | | [0.1269] | [0.0976]** | | [0.1344] | [0.0373]*** | | [0.0135] | [0.0195] | |
| Hispanic | 1.3674 | -0.2212 | | 1.2994 | -1.3050 | | 1.3975 | -0.0250 | | 1.0432 | 0.0466 | |
| | [0.1343]*** | [0.0328]*** | | [0.1243]*** | [0.0835]*** | | [0.1366]*** | [0.0312] | | [0.0135]*** | [0.0156]*** | |
| Cog. score before 2020 | 0.9242 | | | 0.9606 | | | 1.0115 | | | 0.989 | | |
| | [0.0300]** | | | [0.0131]*** | | | [0.0394] | | | [0.0095] | | |
| After infection | | -0.0768 | 0.0471 | | -0.4850 | -0.1620 | | -0.0685 | -0.0965 | | -0.0218 | -0.0439 |
| | | [0.0631] | [0.0788] | | [0.2192]** | [0.2005] | | [0.0560] | [0.0553]* | | [0.0278] | [0.0296] |
| Second test | | 0.1272 | 0.0074 | | -0.5307 | -0.1124 | | 0.1177 | 0.0409 | | 0.1077 | 0.0683 |
| | | [0.1059] | [0.0229] | | [0.5955] | [0.0475]** | | [0.0982] | [0.0151]*** | | [0.0482]** | [0.0097]*** |
| Third test | | 0.0332 | 0.0530 | | -0.9755 | -0.4293 | | 0.0507 | -0.0150 | | 0.0529 | 0.0520 |
| | | [0.0777] | [0.0338] | | [0.5927]* | [0.0754]*** | | [0.0723] | [0.0208] | | [0.0378] | [0.0144]*** |
| Fourth test | | -0.3042 | -0.2732 | | | | | 0.0009 | -0.1204 | | 0.0418 | 0.0353 |
| | | [0.0855]*** | [0.0649]*** | | | | | [0.0788] | [0.0407]*** | | [0.0404] | [0.0272] |
| Constant | 0.3604 | 4.0237 | 5.0920 | 0.3614 | 4.8543 | 8.7488 | 0.2530 | 3.3554 | 4.0301 | 1.2390 | 1.9187 | 1.8832 |
| | [0.0830]*** | [0.0969]*** | [0.4115]*** | [0.0694]*** | [0.6098]*** | [0.7539]*** | [0.0584]*** | [0.0909]*** | [0.2342]*** | [0.0362]*** | [0.0473]*** | [0.1678]*** |
| Observations | 6823 | 8499 | 18433 | 7123 | 8563 | 19090 | 6823 | 7324 | 18454 | 6824 | 7325 | 18453 |
| R-squared | | 0.084 | 0.008 | | 0.420 | 0.014 | | 0.053 | 0.007 | 0.013 | 0.014 | 0.010 |
| Pseudo R-squared | 0.019 | | | 0.020 | | | 0.017 | | | | | |
| Standard errors in brackets | * p<0.10 | ** p<0.05 | *** p<0.01" | | | | | | | | | |

| Table A3: COViD-19 infections and scores for Numeracy, Numbers, Picture Vocabulary, and Verbal Analogies, including time since infection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | OLS | FE | OLS | OLS | FE | OLS | OLS | FE | OLS | OLS | FE |
| | Had covid? | Numeracy | Numeracy | Had covid? | WJ numbers | WJ numbers | Had covid? | WJ Picture Vocabulary | WJ Picture Vocabulary | Had covid? | WJ Verbal Analogies | WJ Verbal Analogies |
| Age | 0.9886 | -0.0562 | -0.0321 | 0.9902 | -0.0481 | 0.1577 | 0.9929 | 0.1649 | 0.0484 | 0.9893 | -0.0658 | -0.0315 |
| | [0.0028]*** | [0.0062]*** | [0.0323] | [0.0029]*** | [0.0068]*** | [0.0484]*** | [0.0031]** | [0.0062]*** | [0.0424] | [0.0030]*** | [0.0065]*** | [0.0431] |
| Currently working | 1.0758 | -0.1267 | | 1.1490 | -0.2273 | | 1.1361 | -0.4013 | | 1.1242 | 0.1565 | |
| | [0.0890] | [0.1854] | | [0.0974] | [0.2019] | | [0.0978] | [0.1850]** | | [0.0976] | [0.1938] | |
| Some College | 1.0676 | 2.7490 | | 1.0554 | 3.0716 | | 1.0391 | 2.8935 | | 1.0397 | 3.0297 | |
| | [0.0982] | [0.2196]*** | | [0.0989] | [0.2386]*** | | [0.0986] | [0.2189]*** | | [0.0991] | [0.2293]*** | |
| Bachelor's or more | 0.7921 | 6.9095 | | 0.7556 | 6.5664 | | 0.6991 | 4.0301 | | 0.7143 | 5.2963 | |
| | [0.0862]** | [0.2335]*** | | [0.0831]** | [0.2541]*** | | [0.0765]*** | [0.2329]*** | | [0.0798]*** | [0.2438]*** | |
| 30000-59999 | 1.0892 | 2.2753 | | 1.1237 | 2.4175 | | 1.0914 | 1.6800 | | 1.1123 | 2.6517 | |
| | [0.1102] | [0.2374]*** | | [0.1176] | [0.2577]*** | | [0.1155] | [0.2367]*** | | [0.1187] | [0.2473]*** | |
| 60000-99999 | 1.0416 | 3.5449 | | 1.1487 | 3.7907 | | 1.0684 | 2.5610 | | 1.0585 | 3.4585 | |
| | [0.1179] | [0.2546]*** | | [0.1328] | [0.2759]*** | | [0.1248] | [0.2537]*** | | [0.1252] | [0.2651]*** | |
| 100000 or more | 0.9791 | 4.9345 | | 1.0688 | 4.7221 | | 1.0264 | 3.4112 | | 1.0647 | 4.3252 | |
| | [0.1239] | [0.2721]*** | | [0.1373] | [0.2959]*** | | [0.1318] | [0.2709]*** | | [0.1382] | [0.2837]*** | |
| male | 0.8496 | 3.7531 | | 0.8220 | 2.9192 | | 0.7911 | 1.3821 | | 0.7778 | 0.3465 | |
| | [0.0666]** | [0.1678]*** | | [0.0647]** | [0.1827]*** | | [0.0628]*** | [0.1668]*** | | [0.0618]*** | [0.1750]** | |
| Separated/Divorced/Widowed | 0.9472 | -0.0500 | | 0.9452 | -0.1989 | | 0.9767 | -0.2215 | | 0.9949 | 0.2072 | |
| | [0.0933] | [0.2221] | | [0.0945] | [0.2415] | | [0.0985] | [0.2203] | | [0.1006] | [0.2311] | |
| Never Married | 0.6261 | 0.6982 | | 0.6487 | 0.5175 | | 0.6549 | 0.1219 | | 0.6477 | 0.1399 | |
| | [0.0642]*** | [0.2223]*** | | [0.0675]*** | [0.2429]** | | [0.0693]*** | [0.2225] | | [0.0694]*** | [0.2340] | |
| Black | 0.9091 | -5.4631 | | 0.9242 | -5.6990 | | 0.8967 | -7.4353 | | 0.9178 | -6.9967 | |
| | [0.1280] | [0.3026]*** | | [0.1318] | [0.3289]*** | | [0.1315] | [0.2985]*** | | [0.1342] | [0.3133]*** | |
| Other non-Hispanic | 0.9909 | 0.3560 | | 0.9976 | -0.4841 | | 0.9349 | -4.6393 | | 0.9830 | -2.3801 | |
| | [0.1279] | [0.2734] | | [0.1311] | [0.2989] | | [0.1256] | [0.2717]*** | | [0.1314] | [0.2847]*** | |
| Hispanic | 1.2728 | -3.5411 | | 1.2841 | -3.5702 | | 1.2405 | -5.0238 | | 1.2704 | -4.4940 | |
| | [0.1217]** | [0.2341]*** | | [0.1267]** | [0.2577]*** | | [0.1303]** | [0.2403]*** | | [0.1337]** | [0.2523]*** | |
| Cog. score before 2020 | 0.9795 | | | 0.9792 | | | 0.9848 | | | 0.9855 | | |
| | [0.0047]*** | | | [0.0046]*** | | | [0.0049]*** | | | [0.0045]*** | | |
| After infection | | 0.1068 | 1.7302 | | -1.2514 | -0.6379 | | -1.2009 | -0.7782 | | -0.7505 | -0.0695 |
| | | [1.0539] | [0.8250]** | | [0.7926] | [0.6106] | | [0.6610]* | [0.5128] | | [0.7113] | [0.6439] |
| time_since_covid | | -0.0057 | -0.0090 | | 0.0033 | 0.0052 | | -0.0039 | 0.0011 | | -0.0058 | -0.0046 |
| | | [0.0049] | [0.0039]** | | [0.0045] | [0.0035] | | [0.0035] | [0.0025] | | [0.0044] | [0.0041] |
| Second test | | -0.3284 | 0.0686 | | 0.1063 | 0.2436 | | 1.7785 | 1.6142 | | 2.9430 | 2.7383 |
| | | [1.5919] | [0.1117] | | [0.2414] | [0.1324]* | | [0.2172]*** | [0.1215]*** | | [0.2324]*** | [0.1300]*** |
| Third test | | -0.6851 | 0.2551 | | 0.7078 | -0.0015 | | 1.4671 | 0.9088 | | 1.5005 | 0.8975 |
| | | [1.5837] | [0.1617] | | [0.2132]*** | [0.2242] | | [0.2000]*** | [0.1957]*** | | [0.2033]*** | [0.2060]*** |
| Constant | 0.8019 | 47.4114 | 52.4441 | 0.7151 | 46.8759 | 43.4512 | 0.5208 | 38.5743 | 48.1111 | 0.5981 | 48.5662 | 52.0074 |
| | [0.2278] | [1.6321]*** | [1.5154]*** | [0.2051] | [0.4771]*** | [2.3259]*** | [0.1419]** | [0.4397]*** | [2.0357]*** | [0.1763]* | [0.4587]*** | [2.0811]*** |
| p-value | | 0.1811 | 0.0682 | | 0.2175 | 0.3198 | | 0.0001 | 0.1522 | | 0.0026 | 0.1758 |
| R-squared | | 0.3246 | 0.0009 | | 0.2611 | 0.0076 | | 0.3537 | 0.0444 | | 0.2417 | 0.0857 |
| Observations | 7126 | 8563 | 19063 | 6885 | 8516 | 18110 | 6702 | 8393 | 18202 | 6583 | 8340 | 17629 |
| Standard errors in brackets | "* p<0.10 | ** p<0.05 | *** p<0.01" | | | | | | | | | |

**Table A4: COViD-19 infections and scores for Serial sevens, self-rated memory (and change), Financial literacy, including time since infection.**

| | Logit | OLS | FE | Logit | OLS | FE | Logit | OLS | FE | Logit | OLS | FE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Had covid?** | **Serial sevens** | **serial sevens** | **Had covid?** | **Financial literacy** | **Financial Literacy** | **Had covid?** | **Self-rated Memory** | **Self-rated Memory** | **Had covid?** | **Memory Change** | **Memory Change** |
| Age | 0.9908 | -0.0007 | -0.0118 | 0.9915 | 0.0427 | 0.0155 | 0.9908 | -0.0029 | -0.0080 | 0.9907 | -0.0016 | -0.0000 |
| | [0.0029]*** | [0.0009] | [0.0087] | [0.0029]*** | [0.0022]*** | [0.0161] | [0.0029]*** | [0.0008]*** | [0.0049] | [0.0029]*** | [0.0004]*** | [0.0035] |
| Currently working | 1.1439 | 0.0396 | | 1.0917 | 0.1118 | | 1.1359 | 0.1150 | | 1.1431 | 0.0244 | |
| | [0.0975] | [0.0261] | | [0.0905] | [0.0662]* | | [0.0967] | [0.0249]*** | | [0.0974] | [0.0122]** | |
| Some College | 1.0279 | 0.2691 | | 1.0630 | 1.2353 | | 1.0101 | 0.1252 | | 1.0117 | -0.0097 | |
| | [0.0959] | [0.0308]*** | | [0.0984] | [0.0784]*** | | [0.0940] | [0.0293]*** | | [0.0940] | [0.0139] | |
| Bachelor's or more | 0.6889 | 0.3832 | | 0.7648 | 2.7961 | | 0.6704 | 0.2352 | | 0.6713 | -0.0049 | |
| | [0.0741]*** | [0.0328]*** | | [0.0843]** | [0.0834]*** | | [0.0720]*** | [0.0314]*** | | [0.0718]*** | [0.0147] | |
| 30000-59999 | 1.1438 | 0.3161 | | 1.0875 | 1.0883 | | 1.1109 | 0.1129 | | 1.1117 | 0.0149 | |
| | [0.1195] | [0.0332]*** | | [0.1106] | [0.0847]*** | | [0.1151] | [0.0317]*** | | [0.1152] | [0.0159] | |
| 60000-99999 | 1.0634 | 0.3415 | | 1.0379 | 1.8042 | | 1.0280 | 0.1889 | | 1.0320 | -0.0164 | |
| | [0.1239] | [0.0358]*** | | [0.1190] | [0.0909]*** | | [0.1191] | [0.0341]*** | | [0.1193] | [0.0167] | |
| 100000 or more | 1.0005 | 0.3975 | | 0.9737 | 2.4126 | | 0.9630 | 0.2760 | | 0.9631 | -0.0073 | |
| | [0.1282] | [0.0381]*** | | [0.1248] | [0.0971]*** | | [0.1227] | [0.0361]*** | | [0.1224] | [0.0175] | |
| male | 0.7905 | 0.0625 | | 0.8191 | 1.1018 | | 0.7861 | 0.0503 | | 0.7897 | 0.0414 | |
| | [0.0618]*** | [0.0236]*** | | [0.0637]** | [0.0599]*** | | [0.0615]*** | [0.0225]** | | [0.0618]*** | [0.0104]*** | |
| Separated/Divorced/Widowed | 1.0035 | 0.0438 | | 0.9496 | -0.0907 | | 0.9975 | -0.1012 | | 0.9961 | -0.0138 | |
| | [0.1001] | [0.0312] | | [0.0935] | [0.0793] | | [0.0994] | [0.0299]*** | | [0.0993] | [0.0141] | |
| Never Married | 0.6749 | 0.0252 | | 0.6206 | 0.1301 | | 0.6731 | -0.0277 | | 0.6754 | -0.0257 | |
| | [0.0703]*** | [0.0313] | | [0.0635]*** | [0.0794] | | [0.0701]*** | [0.0296] | | [0.0704]*** | [0.0144]* | |
| Black | 1.0024 | -0.2595 | | 0.9407 | -1.8327 | | 1.0329 | 0.0472 | | 1.0440 | 0.0987 | |
| | [0.1407] | [0.0424]*** | | [0.1323] | [0.1080]*** | | [0.1442] | [0.0399] | | [0.1461] | [0.0196]*** | |
| Other non-Hispanic | 1.0150 | -0.1169 | | 0.9839 | -0.2234 | | 1.0227 | -0.1737 | | 1.0169 | -0.0033 | |
| | [0.1334] | [0.0386]*** | | [0.1269] | [0.0976]** | | [0.1344] | [0.0373]*** | | [0.1337] | [0.0195] | |
| Hispanic | 1.3674 | -0.2209 | | 1.2994 | -1.3046 | | 1.3975 | -0.0247 | | 1.3968 | 0.0467 | |
| | [0.1343]*** | [0.0328]*** | | [0.1243]*** | [0.0835]*** | | [0.1366]*** | [0.0312] | | [0.1365]*** | [0.0156]*** | |
| Cog. score before 2020 | 0.9242 | | | 0.9606 | | | 1.0103 | | | 0.9112 | | |
| | [0.0300]** | | | [0.0131]*** | | | [0.0393] | | | [0.0757] | | |
| After infection | | -0.0207 | 0.1023 | | -0.4495 | -0.2276 | | -0.0294 | -0.1477 | | -0.0031 | -0.0529 |
| | | [0.1053] | [0.1178] | | [0.3738] | [0.3268] | | [0.0936] | [0.1003] | | [0.0392] | [0.0416] |
| time_since_covid | | -0.0003 | -0.0003 | | -0.0002 | 0.0004 | | -0.0002 | 0.0003 | | -0.0001 | 0.0001 |
| | | [0.0005] | [0.0006] | | [0.0018] | [0.0016] | | [0.0004] | [0.0004] | | [0.0002] | [0.0002] |
| Second test | | 0.1272 | 0.0073 | | -0.5308 | -0.1123 | | 0.1177 | 0.0409 | | 0.1077 | 0.0683 |
| | | [0.1059] | [0.0229] | | [0.5955] | [0.0475]** | | [0.0982] | [0.0151]*** | | [0.0482]** | [0.0097]*** |
| Third test | | 0.0327 | 0.0524 | | -0.9756 | -0.4293 | | 0.0503 | -0.0144 | | 0.0527 | 0.0521 |
| | | [0.0777] | [0.0338] | | [0.5927]* | [0.0754]*** | | [0.0723] | [0.0208] | | [0.0378] | [0.0144]*** |
| Fourth test | | -0.2997 | -0.2692 | | | | | 0.0041 | -0.1241 | | 0.0433 | 0.0346 |
| | | [0.0858]*** | [0.0654]*** | | | | | [0.0790] | [0.0410]*** | | [0.0405] | [0.0273] |
| Constant | 0.3604 | 4.0235 | 5.0909 | 0.3614 | 4.8544 | 8.7482 | 0.2701 | -2.6447 | 4.0311 | 0.2164 | -2.0813 | 1.8834 |
| | [0.0830]*** | [0.0969]*** | [0.4114]*** | [0.0694]*** | [0.6098]*** | [0.7540]*** | [0.0589]*** | [0.0909]*** | [0.2340]*** | [0.0560]*** | [0.0473]*** | [0.1678]*** |
| p-value | | 0.3815 | 0.6750 | | 0.0861 | 0.6946 | | 0.4140 | 0.1928 | | 0.6635 | 0.2779 |
| R-squared | | 0.0845 | 0.0083 | | 0.4200 | 0.0141 | | 0.0527 | 0.0073 | | 0.0139 | 0.0096 |
| Observations | 6823 | 8499 | 18433 | 7123 | 8563 | 19090 | 6823 | 7324 | 18454 | 6824 | 7325 | 18453 |
| Standard errors in brackets | * p<0.10 | ** p<0.05 | *** p<0.01" | | | | | | | | | |

| Table A5: Effect of a covid infection responses to subsequent waves (Fixed Effects) | | | | |
|---|---|---|---|---|
| | Reponse to first wave after infection | Reponse to second wave after infection | Reponse to third wave after infection | Reponse to fourth wave after infection |
| Covid reported this wave | -0.0120 | -0.0208 | 0.0003 | -0.0021 |
| | [0.0097] | [0.0109]* | [0.0101] | [0.0104] |
| Constant | 0.9161 | 0.8680 | 0.0916 | 0.0910 |
| | [0.0001]*** | [0.0001]*** | [0.0001]*** | [0.0001]*** |
| Observations | 173,823 | 167,859 | 167,859 | 167,859 |
| R-squared | 0.000 | 0.000 | 0.000 | 0.000 |
| Pseudo R-squared | | | | |
| Standard errors in brackets | * p<0.10 | ** p<0.05 | *** p<0.01 | |