Evolving Trends in Neuropsychological Profiles of Post COVID-19 Condition: A 1-Year Follow-up in Individuals with Cognitive Complaints

Nicholas Grunden[1], Marco Calabria[2], Carmen García-Sánchez[3], Catalina Pons[4], Juan Antonio Arroyo[5], Beatriz Gómez-Anson[6], Marina del Carmen Estévez García[3], Roberto Belvís[7], Noemí Morollón[7], Monica Cordero Carcedo[3], Isabel Mur[8], Virginia Pomar[8], & Pere Domingo[8]

1. *Department of Psychology, Concordia University, Montreal, Canada*
2. *Cognitive NeuroLab, Faculty of Health Sciences, Universitat Oberta de Catalunya, Barcelona, Spain*
3. *Neuropsychology Unit, Neurology Department, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain*
4. *Facultat de Psicologia, Ciències de l'Educació i l'Esport, Blanquerna, Universitat Ramon Llull, Barcelona, Spain*
5. *Internal Medicine Department, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain*
6. *Neurodiagnostic Department, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain*
7. *Headache Unit, Neurology Department, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain*
8. *Infectious Disease Unit, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain*

Corresponding Author:

Nicholas Grunden
Department of Psychology, Concordia University
7141 Sherbrooke Street West, PY 084.02
Montréal, QC, Canada, H4B 1R6
Email: nicholas.grunden@mail.concordia.ca

Author Note

Author Contributions:

Conceptualization: Nicholas Grunden, Carmen García-Sánchez, Marco Calabria, and Pere Domingo.

Data Curation: Carmen García-Sánchez, Nicholas Grunden, Marco Calabria, Catalina Pons, Juan Antonio Arroyo, Beatriz Gómez-Anson, Marina del Carmen Estévez García, Roberto Belvís, Noemí Morollón, Monica Cordero Carcedo, Isabel Mur, and Virginia Pomar.

Formal Analysis: Marco Calabria and Nicholas Grunden.

Investigation: Carmen García-Sánchez, Catalina Pons, Juan Antonio Arroyo, Beatriz Gómez-Anson, Marina del Carmen Estévez García, Roberto Belvís, Noemí Morollón, Monica Cordero Carcedo, Isabel Mur, and Virginia Pomar.

Methodology: Nicholas Grunden, Carmen García-Sánchez, and Marco Calabria.

Project Administration: Carmen García-Sánchez, Marco Calabria, Nicholas Grunden, and Pere Domingo.

Visualization: Nicholas Grunden.

Writing – Original Draft: Nicholas Grunden.

Writing – Review & Editing: Marco Calabria, Pere Domingo, and Carmen García-Sánchez.

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Abstract

Background: Cognitive difficulties are reported as lasting sequelae within post COVID-19 condition. However, the chronicity of these difficulties and related factors of fatigue, mood, and perceived health have yet to be fully determined. More longitudinal studies are needed to clarify the trends of cognitive test performance and cognitive domain impairment following COVID-19 onset, and whether hospitalization influences outcomes.

Methods: 57 participants who reported subjective cognitive difficulties after confirmed COVID-19 infection were assessed at baseline (~6 months post COVID-19) and follow-up (~15 months later) visits. Assessments included measures across multiple cognitive domains and self-report questionnaires of fatigue, mood, and overall health. Analyses were conducted in three stages: at the test score level (raw and adjusted scores), at the cognitive domain level, and stratified by hospitalization status during infection.

Results: Impacts on cognitive test scores remain stable across assessments. Cognitive domain analyses indicate significant reductions in attention and executive functioning impairment, while memory impairment is slower resolve. On self-report measures, there was a significant improvement in overall health ratings at follow-up. Finally, those hospitalized during infection performed worse on timed cognitive measures across visits and accounted for a larger proportion of cases with short-term and working memory impairment at follow-up.

Conclusions: Cognitive difficulties persist both at test score and cognitive domain levels in many cases of post COVID-19 condition, but evidence suggests some improvement in global measures of attention, executive functioning and overall self-rated health. An effect of hospitalization on cognitive symptoms post COVID-19 may be more discernible over time.

Keywords: post COVID-19 condition, cognitive dysfunction, cognitive changes, longitudinal studies

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In the years since the initial appearance of COVID-19 on the global stage, we have learned more about its pervasive biological impact during both the acute and post-infection disease stages [1]. With a range of labels applied to long-term effects of this disease (e.g., Long Covid, post-acute sequelae of COVID-19, post-COVID-19 syndrome; see the World Health Organization's report [2] for a thorough list of names), the WHO has designated the term "post COVID-19 condition" to describe the lasting symptoms of COVID-19 beyond the period of detectable SARS-CoV-2 infection.

Within a constellation of sequelae in post COVID-19 condition, persisting neuropsychiatric and cognitive difficulties have been consistently observed [3]. In a recent systematic review by Tavares-Júnior and colleagues [4], prevalence of cognitive impairment ranged from 21% to 65% in samples of previously hospitalized COVID-19 survivors tested 12 or more weeks after infection. Common reports months after contracting COVID-19 include troubles with fatigue, brain fog, and issues with attention and memory processes [5, 6]. Comprehensive neuropsychological testing affirms these reports, with cognitive profiles months after disease onset characterized by impaired performance on attentional and executive processing tasks [7–9] and elevated levels of both mental and physical fatigue [10–12] (see Campos et al. [13] for review).

While cognitive impacts of COVID-19 are clearly extending beyond the period of infection, the duration and persistence of these cognitive difficulties in post COVID-19 condition have yet to be fully determined within longitudinal datasets. Baseline/follow-up studies to date have revealed mixed results across various clinical groups. Measured with general cognitive

screening tools such as the Montreal Cognitive Assessment (MoCA [14]), a significant number of participants previously hospitalized with COVID-19 showed improvement between 6- and 12-month follow-up assessments, although group median MoCA scores only increased by one point and 44% of participants' scores still fell in the clinical impaired range [15]. Longitudinal self-report measures in hospitalized patients also reveal subjective reports of improvement in cognitive status but persistent endorsement of memory loss years post hospitalization [16]. Comparing 3- and 12-month follow-up MoCA scores across a range of COVID-19 infection severity groups, researchers found no change in median scores across timepoints but with a lower percentage of scores (18%) falling in clinical range at follow-up [17]. Overall, these studies provide evidence from screening tools of some improvement, but also indicate lasting cognitive impairment (especially in those who were hospitalized with COVID-19) over 1 year after disease onset.

Beyond screening measures, longitudinal studies with comprehensive neuropsychological assessments have begun to provide nuance as to cognitive domains are characteristically impacted in post COVID-19 condition. One longitudinal study with previously hospitalized patients observed improvements in attention/processing speed (T1: 40.8%, T2: 28.3%) and long-term verbal memory (T1: 26.3%, T2: 15.1%) between a 5-month post-COVID assessment and 1-year follow-up [18]. Similarly, another longitudinal study found continuing improvements in immediate verbal memory (RAVLT Immediate) and attentional measures (Trail Making Test A) 1 year after disease onset, albeit in a final sample of 16 participants [19]. A third longitudinal study found little change in cognitive status, with comparable levels of impairment (48-56%) at both 3-month and 1-year post-COVID assessments in previously hospitalized patients [20]. Importantly, all articles stress how findings may include some instances of improvement, but they also

highlight the persistent nature of COVID-19-associated cognitive difficulties one year out. Additionally, they highlight an emerging pattern of long-term cognitive difficulties specifically in memory/learning, attention and executive functioning within post COVID-19 condition, although it remains unclear whether levels of impairment in these domains change over time.

The current study aims to assess evolving trends in the long-term clinical profiles of individuals with cognitive complaints post COVID-19 using a longitudinal dataset of comprehensive neuropsychological assessments. Given that our sample included both individuals who were hospitalized during infection and those who were not, we also sought to explore how hospitalization due to COVID-19, a proxy of disease severity, impacts long-term cognitive profiles. To address these aims, data are analyzed in three stages: (1) at the level of test scores, where measures of cognitive performance, fatigue, depression, anxiety and self-rated health were compared between baseline and follow-up assessments; (2) at the cognitive domain level, where the pervasiveness of cognitive impact at both time points was assessed across various domains of cognitive functioning; and (3) grouped by hospitalization status, where hospitalized versus non-hospitalized participant outcomes were assessed in terms of cognitive tests scores and self-report measures of mood, fatigue, and perceived health, as well as impairment across cognitive domains.

Methods

2.1 Participants

Of the initial 63 subjects included in our baseline study [7], a total of 57 adult participants with post COVID-19 condition completed the follow-up visit (see Figure 1 for recruitment flow chart and Table 1 for total sample characteristics). All participants were (1) symptomatic and tested positive for SARS-CoV-2 via polymerase chain reaction (PCR) and/or serology (anti-

SARS-CoV2 IgM or IgG) at the time of infection, (2) reported subjective cognitive complaints following recovery from acute COVID-19 symptoms, (3) where 18 years or older at the time of infection, and (4) contracted COVID-19 prior to availability of vaccines in Spain (i.e., were unvaccinated at the time of infection). Exclusion criteria included documented history of neurological or psychiatric conditions prior to COVID. The study was approved by the Ethics Committee of Hospital de la Santa Creu i Sant Pau (Ref. Nr. HSCSP-20/117) and all participants signed an informed consent.

Participants were first administered the baseline neuropsychological battery an average of 191.00 days (SD = 99.32) after their COVID-19 diagnosis. At that time, participants met the World Health Organization's definition of *post COVID-19 condition*, with confirmed SARS-CoV-2 infection and clinical symptoms present 3 months after the onset of COVID-19 [21]. Follow-up testing occurred an average of 630.28 days post COVID-19 diagnosis (SD = 145.26), with an average time of 439.28 days (SD = 97.50) between evaluations.

[INSERT FIGURE 1 AND TABLE 1 HERE]

2.2 Neuropsychological Assessment

The follow-up visit consisted of the same comprehensive battery of cognitive measures as administered at baseline visit (see Table 2 for neuropsychological tests and Supporting Information for test overview and normative data used). Parallel forms of the MoCA and RAVLT were used at baseline and follow-up assessments to negate practice effects.

Other clinically relevant factors were also measured at baseline and follow-up: fatigue, measured with the Modified Fatigue Impact Scale (MFIS) [22]; depression and anxiety, measured with the Hospital Anxiety and Depression Scale (HADS) [23]; and self-rated health on a visual analogue scale of current overall health status from the EQ-5D [24].

[INSERT TABLE 2 HERE]

2.3 Analyses

All data entry, inspection, cleaning, and analyses were performed using JASP [25] and the following R packages in RStudio [26]: *tidyverse* [27] and *stats* [28].

2.3.1 Test-level analyses

Baseline and follow-up raw scores were obtained from cognitive measures. Age- and education-corrected T-scores were then derived using Spanish normative data (see Supporting Information for norms). These adjusted scores were classified into the following clinically relevant categories of performance, following consensus guidelines for labeling cognitive test scores from the American Academy of Clinical Neuropsychology (AACN) [29]: Below average/Exceptionally low (Pc < 8), Low average (Pc: 9-24), or Average and above (Pc > 25). MoCA scores (version without visual components, max. = 22) were excluded from this classification system, instead using a clinical cut-off score of 18 [30].

Test-level analyses utilized both raw and adjusted test scores. First, we analyzed raw test scores by performing repeated-measures ANOVAs with Time (baseline vs. follow-up) entered as a within-subjects factor for each raw score on cognitive measures (excluding CPT scores) as well as clinical scores of fatigue, depression and anxiety, and self-rated health. Period since infection (due to varying intervals between infection and assessments), age, education, and sex were controlled for as covariates within these analyses. Marginal means and test statistics were reported for all significant findings.

Second, we analyzed the distribution of adjusted scores for each cognitive test within the AACN classification system, creating a categorical distribution of scores at baseline and follow-up assessments. McNemar-Bowker tests of symmetry were conducted using proportions of

cognitive test scores falling into the three ranges of performance to determine significant changes between the two timepoints. For MoCA scores, proportions of scores falling above and below the cut-off score of 18 at baseline and follow-up were compared.

2.3.2 Domain-level analyses

Cognitive tests at the follow-up study were grouped into domains following the same Principal Components Analysis factors obtained at baseline to aid comparison between timepoints [7]: Learning and Long-term Memory (L+LTM), Visuospatial and Visuoconstructive Abilities (VVA), Short-Term and Working Memory (ST/WM), Processing Speed (PS), Language, Attention, and Executive Functioning (EF). A cognitive domain was considered impaired if it met one of the following conditions: (a) at least 50% of the test scores were labelled as Below average/Exceptionally low; (b) at least 50% of the test scores were Below average/Exceptionally low for tests having single scores; (c) at least 30% of the test scores were Below average/Exceptionally low and 30% of the test scores were labelled as Low average.

To characterize cognitive domain impairment, percentages of affected domains were described at baseline and follow-up. McNemar tests were run to identify significant changes across time between proportions of affected versus non-affected cases in each cognitive domain.

2.3.3 Effect of hospitalization

Analyses examining the effect of hospitalization included mixed ANOVAs using raw scores, with Time as within-subject factor and Hospitalization (hospitalized vs. non-hospitalized) entered as a between-subjects factor. The same covariates (period since infection, age, education, and sex) as previous ANOVAs were utilized. Statistical techniques comparing a 3 x 3 paired samples design stratified by group are not currently available [31]; consequently, it was not

possible to extend McNemar-Bowker tests with adjusted test scores to compare hospitalization status within these analyses.

At the domain level, Pearson's chi-squared tests of independence were performed for all cognitive domains comparing the frequency of affected domains in hospitalized versus non-hospitalized participants at follow-up assessment.

Results

3.1 Test-level Results Over Time

3.1.1 Raw test scores at baseline and follow-up

Repeated-measures ANOVAs revealed no statistically significant differences in cognitive performance on neuropsychological measures between assessments ($p > .050$), with the exception of higher scores at follow-up ($M = 88.494$, $SE = 2.846$) compared to baseline ($M = 88.919$, $SE = 3.530$) on Stroop – Word reading ($F_{(1,49)} = 4.273$, p = .044, $\eta^2 = .017$).

For non-cognitive clinical measures, repeated-measures ANOVAs did not reveal any statistically significant effects of Time (baseline vs. follow-up) on total fatigue score, anxiety or depression scores ($p > .050$), but there was a significant increase in self-rated health ($F_{(1,51)} = 5.950$, p = .018, $\eta^2 = .021$) from baseline ($M = 8.665$, $SE = 1.694$) to follow-up ($M = 9.760$, $SE = 1.694$).

3.1.2 Adjusted test scores at baseline and follow-up

McNemar-Bowker tests comparing proportions of adjusted scores in AACN categories (Below Average/Exceptionally Low, Low Average, and Average) revealed no statistically significant changes between baseline and follow up ($p > .050$). A McNemar test comparing proportions of MoCA scores falling above and below cut-off also revealed no significant

differences between assessment points. See Table 2 for score distribution and test results and Figure 2 for visual distributions of test scores at baseline and follow-up assessments.

[INSERT FIGURE 2 HERE]

3.2 Domain-level Results Over Time

While all participants exhibited at least one cognitive domain classified as affected at baseline, 35.09% of participants did not have any affected domains at follow-up. Attention was the most commonly affected cognitive domain at baseline (59.65%) and follow-up (33.33%). This was followed by L+LTM (baseline: 42.11%, follow-up: 31.58%), EF (baseline: 42.11%, follow-up: 21.05%), and ST/WM (baseline: 31.58%, follow-up: 21.05%). The remaining cognitive domains were affected less frequently at follow up (Language: 10.53%, PS: 3.51%, and VVA: 12.28%).

Statistically significant differences in proportions of affected cognitive domains between timepoints were found for Attention (McNemar's $\chi^2 = 7.26$, $p = .007$, Cohen's $g = .24$) and EF (McNemar's $\chi^2 = 12.00$, $p < .001$, Cohen's $g = .50$). For Attention, 23 of those participants impaired at baseline converted to unimpaired at follow-up and 8 of those unimpaired at baseline were impaired at follow-up. For EF, 12 impaired cases at baseline were unimpaired at follow-up while none of the unimpaired cases became impaired. See Figure 3 for flow diagrams of Attention and EF impairment.

[INSERT FIGURE 3 HERE]

3.3 Effects of Hospitalization

See Table 1 for sample characteristics by hospitalization group. There was a statistically significant difference in sex between groups, with a higher percentage of women in the non-hospitalized group (80%) than in the hospitalized group (48%; $\chi^2 = 6.33$, $p = .012$).

At test level, mixed ANOVAs performed on raw scores revealed no significant effects of Time in cognitive performance between baseline and follow-up assessments, except for Stroop – Word Reading (baseline: $M = 88.440$, $SE = 2.759$; follow-up: $M = 88.854$, $SE = 3.430$; $F_{(1,48)} = 4.054$, $p = .050$, $\eta^2 = .017$). The increase in self-rated health over time remained statistically significant (baseline: $M = 8.758$, $SE = 1.696$; follow-up: $M = 9.857$, $SE = 1.696$; $F_{(1,50)} = 5.721$, $p = .021$, $\eta^2 = .020$).

A main effect of Hospitalization in mixed ANOVAs was revealed for the following cognitive tests: ROCFT – Time (Non-hospitalized: $M = 134.321$, $SE = 72.481$; Hospitalized: $M = 177.403$, $SE = 71.474$; $F_{(1,50)} = 5.389$, $p = .024$, $\eta^2 = .060$), WAIS – Coding (Non-hospitalized: $M = 64.254$, $SE = 13.845$; Hospitalized: $M = 52.203$, $SE = 13.652$; $F_{(1,50)} = 11.556$, $p = .001$, $\eta^2 = .116$), WAIS – Symbol Search (Non-hospitalized: $M = 23.410$, $SE = 7.240$; Hospitalized: $M = 18.148$, $SE = 7.140$; $F_{(1,50)} = 8.057$, $p = .007$, $\eta^2 = .100$), and Stroop – Word Reading (Non-hospitalized: $M = 94.910$, $SE = 3.861$; Hospitalized: $M = 82.384$, $SE = 3.899$; $F_{(1,48)} = 5.142$, $p = .028$, $\eta^2 = .069$). On these tests, participants who were hospitalized due to COVID-19 performed poorer than those who were not hospitalized at the time of infection. There was no effect of Hospitalization on clinical measures of fatigue, depression, anxiety or self-rated health.

At the domain level during follow-up, the group of participants with no impaired domains at follow-up was made up of 65% non-hospitalized and 35% previously hospitalized participants. Examining specific domains, hospitalized individuals exhibited a significantly higher proportion of cases with ST/WM impairment compared to non-hospitalized patients ($\chi^2 = 4.66$, $p = .031$, adjusted Cramer's V = .25), with 50% of those hospitalized demonstrating impairment in short term/working memory versus only 11% of those who were not hospitalized classified as impaired. All chi-squared tests of independence for other cognitive domains revealed no

significant proportional differences in impairment between hospitalized and non-hospitalized participants.

Discussion

The current study examined how cognitive performance and related clinical factors in a group of individuals with cognitive complaints related to post COVID-19 condition evolved over one year between baseline and follow-up neuropsychological assessments. To do so, analyses looked at not only quantitative change in raw test scores, but also changes in scaled test score distributions, changes in impairment at the cognitive domain level, and the effect of hospitalization on long-term recovery.

Overall, our findings suggest that cognitive impairment in test performance persists well beyond one year after COVID-19 infection. Test-level analyses reveal very little significant change in cognitive performance over time when controlling for covariates. Comparing raw scores, only one task of reading speed showed significant change, with a very modest effect size. While there were some shifts in adjusted test score distributions across the two assessments (see Figure 2), none of these changes in proportions were significant.

At the domain level, there was mixed evidence of cognitive change. There was some indication of improvement, with ⅓ of the sample converting from at least one affected domain to no impaired domains. Furthermore, there were significant reductions in proportions of individuals with impairment in Attention and EF domains. In Attention, there were mixed trajectories of participants, with some examples of decline (14.04% of total sample) but an overall group shift towards unimpaired status (40.35% of total sample). In EF, there was a clearer pattern of remission, with half of impaired cases becoming unimpaired (21.05% of total sample)

and all previously unimpaired individuals (57.89% of total sample) remaining unimpaired at follow-up. These patterns of improvement, albeit mixed, may contribute to the significant increases in self-rated health observed in our study, and reflect qualitative findings of self-reported improvement in cognitive abilities previously observed in post COVID-19 condition [32]. There has been some debate over how associated subjective reports and objective measures of cognitive impairment are in this population [33, 34]. In our sample, subjective improvements seem to be mirrored by objective measures when analyzed at a more global domain level and less associated with changes at the test score level. Given this, cognitive functioning measured at the domain level seems to be more reflective of individuals' experiences of improvement in cognitive abilities.

However, in conjunction with evidence of improvement, our findings at the domain level also revealed some patterns of lasting cognitive impairment. At follow-up, ⅕ of participants in our total sample were still impaired in EF and ST/WM and ⅓ of the total sample was impaired in Attention and L+LTM at follow-up. This larger picture of some improvement mixed with continued impairment is consistent with previous findings. Comparable studies have reported a common impact in memory, attention, and EF processes, while impairment in language and visuospatial abilities is relatively uncommon [18–20] (for review, see Bertuccelli et al. [3]). Along with some nuanced differences between studies' findings, the overarching agreement is that these three cognitive processes are the most heavily hit in post COVID-19 condition. Interestingly, while Attention and EF domains may demonstrate partial recovery in our sample, results suggest that proportions of domain-level impairment in memory (L+LTM and ST/WM) remain more stable over time. Ferrucci et al. [18] and Diana et al. [19] also found trends of

improvement in attention and executive functioning at one year post COVID-19 onset and beyond. While they also found reductions in memory impairment, their combined findings were more ambiguous, with Ferrucci and colleagues reporting improvement in verbal but not visual memory tasks whereas Diana et al.'s findings indicated improvement on verbal learning (not recall) and in long-term visual memory. Our own results, along with those of these similar longitudinal neuropsychological studies, seem to suggest a pattern of partial recovery in attention and executive functioning abilities while recovery of memory processes, both short-term/working and long-term, seems to be less well-defined over time.

Hospitalization, an unspecific proxy for disease severity at the time of infection, appears to have lasting impacts on long-term cognitive performance in post COVID-19 condition. In our sample, scores on multiple timed tests were routinely lower in the hospitalized group compared to the non-hospitalized group. Becker et al. [35] found similar results, where hospitalized patients were more likely to be impaired across a variety of cognitive measures. Additionally, the proportion of hospitalized patients with impairment in ST/WM (50%) was significantly higher than the proportion of non-hospitalized participants (13%). This is in line with the findings of Vannorsdall and colleagues [9], who reported more frequent long-term impairment in working memory and executive functioning (indexed by oral administration of TMT B, which would have a high loading of working memory given the modality) in ICU patients. Given the pattern of worse performance on timed tasks and impaired working memory, patients hospitalized with COVID-19 may exhibit a long-term profile of cognitive slowing, requiring more time to complete cognitively demanding tasks.

Despite this pattern, other studies have found little effect of hospitalization on cognitive performance [8, 36, 37], including our own cross-sectional study where we found hospitalized patients only performed worse on MoCA and WAIS – Coding tests [7]. This may be due to a question of time. As cognitive sequelae evolve over the long term after COVID-19 infection (on average 1¾ years in the current study), performance of hospitalization groups may become sufficiently differentiated, with hospitalized patients ultimately demonstrating worse performance on timed tasks and in the working memory domain. Indeed, Fernández-de-las-Peñas et al. [16] found persistent reports of memory difficulties up to 40 months after COVID-19 in hospitalized patients. A review by Ceban et al. [11] found higher proportions of cognitive impairment in hospitalized (30%) versus non-hospitalized (20%) individuals; although this difference did not reach statistical significance, follow-up periods in their meta-analysis ranged from 2.8 to 11.2 months and may not have captured a long-term differentiation between groups. Thus, hospitalization due to COVID-19, and the disease severity that it reflects, may become more consequential for cognitive problems in the *years* after disease onset.

Some of the limitations of this study include a lack of premorbid measures of cognitive functioning in our sample prior to their COVID-19 infection. Knowledge of functioning prior to COVID-19 infection would allow for more causal claims about the etiology of patients' deficits. Furthermore, this study only consisted of individuals who had already reported subjective cognitive complaints. Although this represents a subpopulation of COVID-19 survivors that is of particular research interest, the propensity to report cognitive complaints may be associated with other personality, psychological (e.g., anxiety), and demographic factors specifically within the

post COVID-19 condition population [33]. This might hinder the generalizability of our findings.

In conclusion, our results indicate that, in individuals with subjective cognitive complaints post COVID-19, objective cognitive impairment in test scores lingers well over a year past COVID-19 onset. Findings at the cognitive domain level do offer some indication of improvement in attention and executive functioning, with less evidence of change in memory impairment and consistently (low) levels of impairment within other cognitive domains. In parallel, overall participant health ratings show significant improvements over time. Hospitalized patients scored consistently lower than their non-hospitalized counterparts on timed tasks, revealing an effect of hospitalization that may only become significant in the long term (1+ years post COVID-19 onset). Future research should build upon predictive models of long-term cognitive difficulties [38] to clarify what factors shape an individual's post COVID-19 condition pattern of recovery.

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Tables

Table 1. Sociodemographic information for total sample and by hospitalization group.

	Total Sample	Status during COVID-19 diagnosis		*p*
		Non-hospitalized	Hospitalized	
N	**57**	30	27	
Sex				0.012
Females (%)	**37 (65)**	24 (80)	13 (48)	
Males (%)	**20 (35)**	6 (20)	14 (52)	
Age				
Mean (SD)	**51.70 (12.80)**	48.63 (12.95)	55.11 (11.96)	0.056
Education				
Mean (SD)	**14.34 (3.28)**	14.57 (3.26)	14.08 (3.35)	0.582

Note. Reported p-values are derived from a chi-square test for sex and independent-samples t-tests for age and education.

Table 2. Test score distribution across AACN classifications of cognitive performance at baseline and follow-up assessments.

	Baseline				Follow-up				McNemar-Bowker Tests of Symmetry	
	Below average/Exceptionally low (Pc < 8)	Low average (9 ≤ Pc < 24)	Average or above (Pc > 25)	Missing	Below average/Exceptionally low (Pc < 8)	Low average (9 ≤ Pc < 24)	Average or above (Pc > 25)	Missing	χ^2	*p*-value
Learning and Long-term Memory (L+LTM)										
RAVLT										
Trial 1	10 (17.54)	10 (17.54)	37 (64.91)	–	20 (35.09)	11 (19.3)	26 (45.61)	–	6.095	.107
Trial 5	9 (15.79)	9 (15.79)	39 (68.42)	–	14 (24.56)	8 (14.04)	35 (61.4)	–	1.596	.660
Total	12 (21.05)	16 (28.07)	29 (50.88)	–	20 (35.09)	11 (19.3)	26 (45.61)	–	5.303	.151
Delayed Recall	13 (22.81)	7 (12.28)	37 (64.91)	–	12 (21.05)	7 (12.28)	38 (66.67)	–	0.111	.990
Recognition	13 (22.81)	3 (5.26)	41 (71.93)	–	11 (19.3)	3 (5.26)	43 (75.44)	–	0.286	.897
ROCFT										
Delayed Recall	13 (22.81)	15 (26.32)	29 (50.88)	–	5 (8.77)	14 (24.56)	38 (66.67)	–	5.471	.140

Visuospatial and Visuoconstructive Abilities (VVA)										
ROCFT										
Copy Trial	5 (8.77)	14 (24.56)	38 (66.67)	–	11 (19.3)	12 (21.05)	34 (59.65)	–	3.452	.327
Time	5 (8.77)	7 (12.28)	45 (78.95)	–	1 (1.75)	10 (17.54)	46 (80.7)	–	3.077	.380
WAIS-IV										
Block Design	2 (3.51)	8 (14.04)	47 (82.46)	–	3 (5.26)	6 (10.53)	48 (84.21)	–	1.077	.783
Short-Term and Working Memory (ST/WM)										
WAIS-IV										
Forward Digit Span	15 (26.32)	6 (10.53)	36 (63.16)	–	11 (19.3)	9 (15.79)	37 (64.91)	–	4.523	.210
Backward Digit Span	6 (10.53)	5 (8.77)	46 (80.7)	–	3 (5.26)	10 (17.54)	44 (77.19)	–	5.571	.134
Processing Speed (PS)										
WAIS-IV										
Coding	4 (7.02)	6 (10.53)	47 (82.46)	–	2 (3.51)	9 (15.79)	46 (80.7)	–	1.833	.608

Symbol Search	3 (5.26)	5 (8.77)	49 (85.96)	–	2 (3.51)	5 (8.77)	50 (87.72)	–	0.333	.846
Language										
BNT	4 (7.02)	4 (7.02)	49 (85.96)	–	2 (3.51)	4 (7.02)	51 (89.47)	–	0.667	.717
Verbal Fluencies										
Phonemic	9 (15.79)	10 (17.54)	38 (66.67)	–	3 (5.26)	9 (15.79)	45 (78.95)	–	5.886	.117
Semantic	12 (21.05)	6 (10.53)	39 (68.42)	–	10 (17.54)	8 (14.04)	39 (68.42)	–	3.202	.362
Attention										
CPT-II										
Omissions %	18 (31.58)	10 (17.54)	29 (50.88)	–	13 (22.81)	10 (17.54)	34 (59.65)	–	2.992	.393
Comissions %	14 (24.56)	13 (22.81)	30 (52.63)	–	15 (26.32)	10 (17.54)	32 (56.14)	–	0.476	.924
Hit RT	23 (40.35)	9 (15.79)	25 (43.86)	–	21 (36.84)	15 (26.32)	21 (36.84)	–	3.067	.381
Hit SE	31 (54.39)	13 (22.81)	13 (22.81)	–	22 (38.6)	20 (35.09)	15 (26.32)	–	7.231	.065
Variability	24 (42.11)	16 (28.07)	17 (29.82)	–	19 (33.33)	23 (40.35)	15 (26.32)	–	3.359	.340

Detectability (d')	13 (22.81)	23 (40.35)	21 (36.84)	–	10 (17.54)	18 (31.58)	29 (50.88)	–	5.800	.055
Response Style (β)	10 (17.54)	14 (24.56)	33 (57.89)	–	15 (26.32)	14 (24.56)	28 (49.12)	–	2.119	.548
Perseverations %	18 (31.58)	1 (1.75)	38 (66.67)	–	20 (35.09)	1 (1.75)	36 (63.16)	–	0.222	.895
Hit RT Block Change	9 (15.79)	15 (26.32)	33 (57.89)	–	10 (17.54)	15 (26.32)	32 (56.14)	–	2.393	.495
Hit SE Block Change	13 (22.81)	26 (45.61)	18 (31.58)	–	13 (22.81)	20 (35.09)	24 (42.11)	–	4.286	.232
Hit RT ISI Change	16 (28.07)	19 (33.33)	22 (38.6)	–	19 (33.33)	15 (26.32)	23 (40.35)	–	0.895	.827
Hit SE ISI Change	14 (24.56)	16 (28.07)	27 (47.37)	–	16 (28.07)	15 (26.32)	26 (45.61)	–	0.477	.924
Executive Functioning (EF)										
Trail Making Test										
A	8 (14.04)	13 (22.81)	36 (63.16)	–	8 (14.04)	7 (12.28)	42 (73.68)	–	6.086	.108
B	10 (17.54)	15 (26.32)	30 (52.63)	2 (3.51)	8 (14.04)	10 (17.54)	38 (66.67)	1 (1.75)	5.655	.130
Stroop Test										
Word Reading	15 (26.32)	14 (24.56)	26 (45.61)	2 (3.51)	17 (29.82)	9 (15.79)	29 (50.88)	2 (3.51)	2.444	.485

Color Naming	16 (28.07)	11 (19.3)	28 (49.12)	2 (3.51)	14 (24.56)	10 (17.54)	31 (54.39)	2 (3.51)	2.300	.513
Inhibition	13 (22.81)	8 (14.04)	34 (59.65)	2 (3.51)	7 (12.28)	13 (22.81)	35 (61.4)	2 (3.51)	3.778	.286

Note. Count of participants (percentage of sample) within each AACN performance category reported for each test score. RAVLT = Rey Autidory Verbal Learning Test, ROCFT = Rey-Osterrieth Complex Figure Test, WAIS-IV = Wechsler Adult Intelligence Scale IV, BNT = Boston Naming Test, CPT-II = Conners' Continuous Performance Test II, RT = Reaction Time, SE = Standard Error, ISI = Inter-Simulus Interval.

Figures

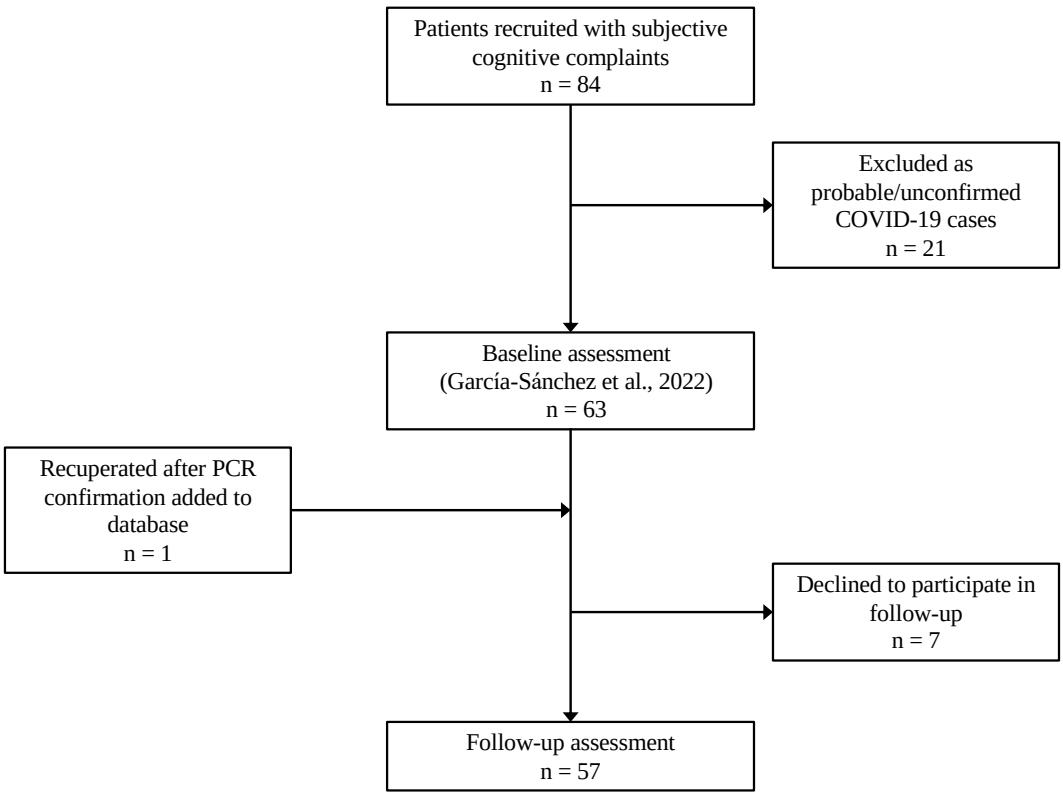

Figure 1. Participant recruitment flow chart for baseline and follow-up studies.

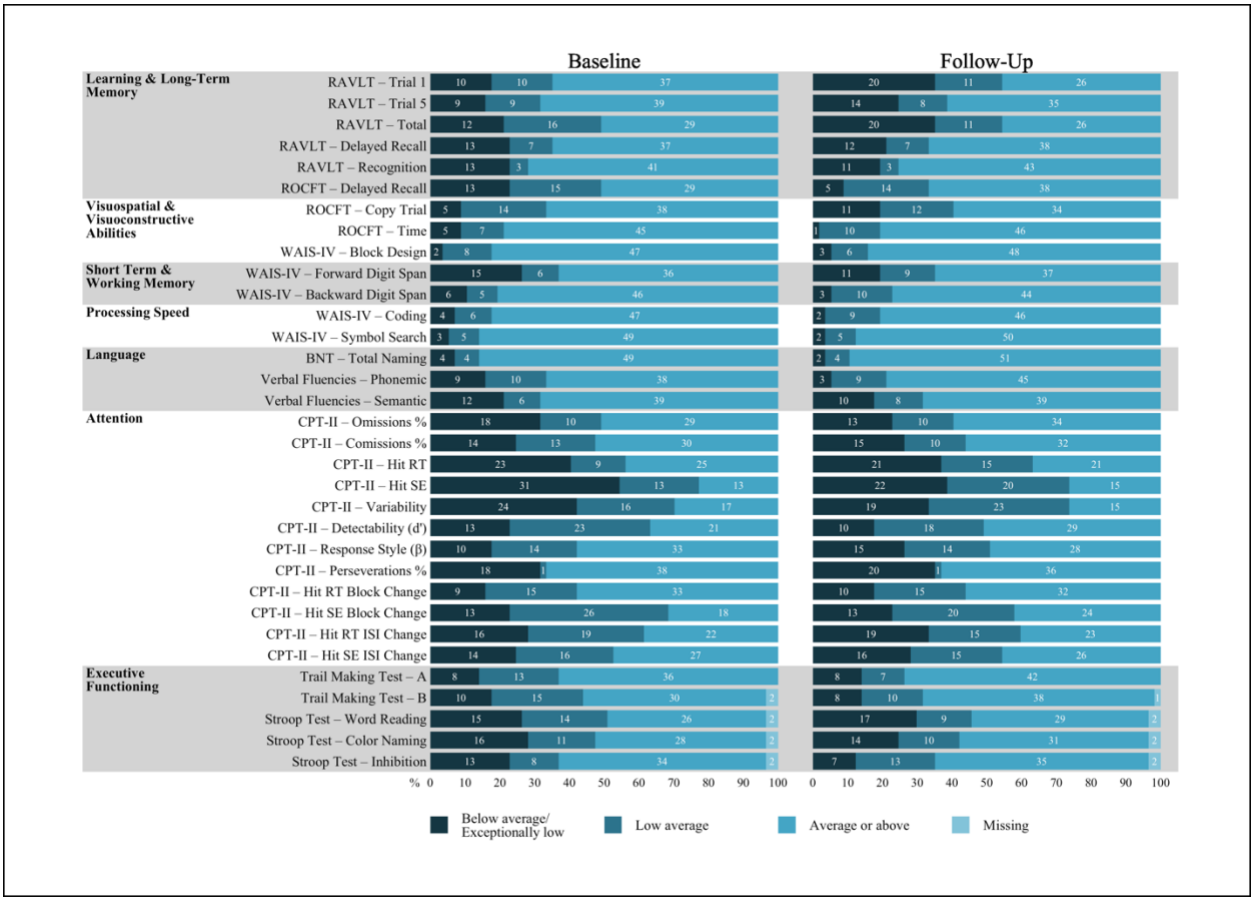

Figure 2. Cognitive test score distribution for baseline and follow-up visits. RAVLT = Rey Auditory Verbal Learning Test, ROCFT = Rey-Osterrieth Complex Figure Test, WAIS-IV = Wechsler Adult Intelligence Scale IV, BNT = Boston Naming Test, CPT-II = Conners' Continuous Performance Test II, RT = Reaction Time, SE = Standard Error, ISI = Interstimulus Interval.

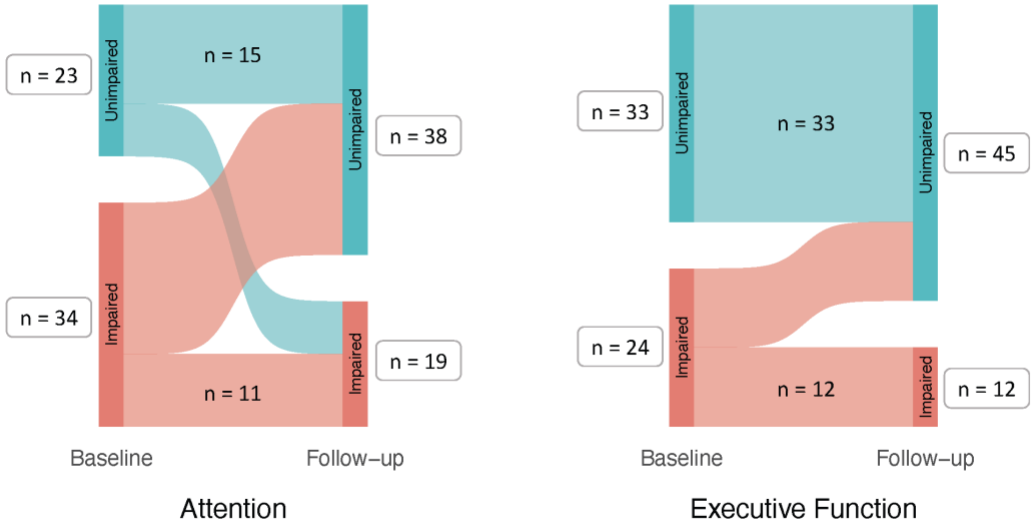

Figure 3. Flow diagrams between baseline and follow-up visits of impaired versus unimpaired cases in Attention and EF domains.