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Cognitive-linguistic difficulties in adults with Long COVID: A follow-up study

Louise Cummings [*,1]

The Hong Kong Polytechnic University, Hong Kong, China

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ABSTRACT

As the emergency phase of the COVID-19 pandemic subsides, the long-term health problems caused by SARS-CoV-2 infection are becoming increasingly clear. So-called Long COVID, or post COVID-19 condition, is a debilitating illness that impacts functioning for months and even years after infection. Alongside physical symptoms, Long COVID has a particularly insidious effect on cognition and language. While many studies have documented non-linguistic cognitive impairments in people with Long COVID, what has not been documented to any significant extent is the presence and duration of language difficulties in Long COVID. This study addresses this lack of research by examining the cognitive-linguistic skills of 41 adults with Long COVID. These adults were assessed at two time points using a test protocol of 12 language tasks. This paper describes the findings of the 6-month follow-up study. Results indicate that difficulties in immediate and delayed verbal recall persist long after the onset of COVID symptoms, even as improvements occur in verbal fluency and the informativeness of spoken discourse. It is argued that these difficulties are a significant contributing factor in a lack of work return in these adults. Implications of these findings for the provision of speech-language pathology services to these adults and occupational health policies relating to Long COVID are discussed.

"My partner is 41, a primary school teacher who previously would have been in the top 5 percent for expressive language and related cognitive tasks — and he can't work out how to answer whether or not he wants a coffee when I ask."

Partner of 41-year-old man with Long COVID, 12 months post onset (Australia)

1. Introduction

The COVID-19 pandemic has undoubtedly been the global health challenge of our time. But aside from the large number of deaths caused by SARS-CoV-2 (the virus that causes COVID-19), an even greater number of people with long-term debilitating illness could yet be the legacy of this pandemic. As we learn more about the pathophysiological effects of SARS-CoV-2 (Perumal et al., 2023), it is clear that a large burden of cognitive impairment exists alongside physical symptoms in people with Long COVID. Cognition is not a unitary phenomenon but consists of linguistic and non-linguistic components that interact in complex ways. While considerable research has been conducted into non-linguistic aspects of cognition such as memory and attention in people with Long COVID, there has been relatively little research undertaken into how language is compromised in this condition. The current paper addresses this lack of research by examining cognitive-linguistic difficulties in adults with Long COVID. The 41 adults examined in this study were previously assessed by the author, with the results reported in Cummings (2023a). These individuals were assessed again at six months after the first assessment with a view to determining if their cognitive-linguistic difficulties had improved, deteriorated, or remained static. This article reports the results of this 6-month follow-up study. It also considers the role that cognitive-linguistic difficulties play in low rates of work return in adults with Long COVID.

The article unfolds along the following lines. Long COVID is introduced in Section 2. Cognitive dysfunction is a widely recognized feature

* Correspondence to: Department of English and Communication, Chung Sze Yuen Building, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China.

E-mail address: louise.cummings@polyu.edu.hk.

[1] Orcid ID: https://orcid.org/0000-0002-8947-8195

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of the post COVID-19 condition. Section 2 considers the prevalence of cognitive dysfunction in Long COVID and examines some of the cognitive-linguistic behaviours that people with Long COVID include within self-reports of "brain fog". The study conducted by Cummings (2023a) provides background to the current investigation. Its findings are examined in Section 2 and the case is made that Long COVID-related language and communication difficulties should be examined longitudinally. A 6-month follow-up study of 41 adults with Long COVID is the focus of the current article. The participants and tasks included in this study along with its results are presented in Section 3. In Section 4, the results of the follow-up study are discussed in detail. The responses of participants with Long COVID to some of the tasks in the study are used to illustrate specific language difficulties. Finally, wider implications of the study are considered in Section 5.

2. Long COVID and "brain fog"

When the SARS-CoV-2 virus first emerged in late 2019, governments and health authorities around the world issued repeated public reassurances that COVID-19 would be a mild illness from which most people would make a complete recovery within a couple of weeks (House of Commons, 2020). It was not long into the pandemic before reports began to emerge that suggested this was quite often not the case. People with COVID-19 started to organize themselves into online groups and share stories about the continuing symptoms that they were experiencing. Some had returned to work after an apparently good recovery only to find themselves unable to cope with debilitating fatigue and other symptoms and having to take a further period of sickness absence (Cummings, 2023a). Poor understanding and dismissal of symptoms by medical professionals was commonly reported, with many individuals incorrectly diagnosed with conditions such as anxiety and depression. Over time, it became apparent that the problems these individuals were experiencing were not psychosomatic in nature and that for a significant number of people, what had started out as a mild illness had gone on to have serious, longer-term consequences for their health. The label "Long COVID" was coined to capture this mysterious new illness, with those who were experiencing it often referred to as COVID long haulers.

Today, Long COVID is recognized around the world as a significant condition that occurs in 10%– 20% of all COVID infections (World Health Organization, 2023). The condition has an unpredictable course that makes it difficult to manage its impact on daily life. New-onset symptoms can exist alongside symptoms that persist from the initial acute infection. Importantly, the illness is characterized by physical *and* cognitive symptoms ("cognitive dysfunction"), as the following clinical case definition of the "post COVID-19 condition" from the World Health Organization (2021) makes clear:

> "Post COVID-19 condition occurs in individuals with a history of probable or confirmed SARS CoV-2 infection, usually 3 months from the onset of COVID-19 with symptoms and that last for at least 2 months and cannot be explained by an alternative diagnosis. Common symptoms include fatigue, shortness of breath, cognitive dysfunction but also others and generally have an impact on everyday functioning. Symptoms may be new onset following initial recovery from an acute COVID-19 episode or persist from the initial illness. Symptoms may also fluctuate or relapse over time."

Informally termed "brain fog", cognitive dysfunction in Long COVID has been the focus of a large number of studies to date. Delgado-Alonso et al. (2022) examined 50 patients with COVID-19 who reported cognitive problems 9.12 ($\pm$ 3.46) months after acute infection. These patients displayed reduced performance on several tests of attention and executive function. There were alterations in processing speed, divided and selective attention, visual vigilance, intrinsic alertness, working memory, and inhibition; episodic memory; and visuospatial processing. Hadad et al. (2022) examined cognitive functioning in 46 patients (mean age = 49.5 years) at a post COVID clinic in Northern Israel. These patients displayed impairments of executive functions, particularly phonemic fluency, and attention on the Montreal Cognitive Assessment. Disease severity, premorbid condition, pulmonary function tests and hypoxia did not contribute to cognitive performance in these patients. Cognitive problems have also been reported in people who have recovered from COVID-19, including those who no longer report symptoms (Hampshire et al., 2021). (But see Priftis et al. (2022) who did not find evidence of neuropsychological disorders in 22 adults (mean age: 58 years) with severe COVID-19 disease who were tested on average 81 days after onset.).

One aspect of cognition that has received relatively little attention in research into Long COVID is language. This is despite the fact that people with Long COVID and brain fog often report, and exhibit, significant language and communication difficulties as part of their condition. Chalmers et al. (2023) examined clinician identified need in adults with Long COVID who were referred to two National Health Service (NHS) trusts in the UK between 1 January 2021 and 1 January 2022. In one trust (East Suffolk), cognitive-communication difficulties were identified in 52.6% (40/76) of patients. This contrasted with 14.1% of patients (11/78) in the second NHS trust (Bolton). The authors explained this difference in terms of service pathways. The service in Bolton had access to a multidisciplinary team that contained occupational therapists with specialist skills in cognition. This meant that, unlike in East Suffolk, fewer adults with cognitive difficulties were referred to speech and language therapy in Bolton.

Cummings (2023b) examined language and communication difficulties in 973 adults who responded to an online Long COVID survey. These participants (mean age = 47.4 years) were asked to indicate if they experienced 11 language and communication problems as part of their Long COVID illness. Table 1 lists the frequency of these problems among the respondents in the study. The table shows that these difficulties had a high prevalence among participants, with nine of 11 behaviours reported in over 50% of respondents. Additionally, 83.2% of respondents reported feeling frustrated by their communication skills following COVID-19, 54.9% were embarrassed by their post-COVID communication skills, 71.3% reported communicating less frequently after COVID-19, and 65.8% had less desire to communicate. These figures clearly indicate that a sizeable burden of language and communication difficulty accompanies "brain fog" in Long COVID.

To understand the nature of these language and communication difficulties, Cummings (2023a) conducted a study of 92 adults with Long COVID. Of these adults, 81 reported brain fog as part of their condition. These adults, who had an average age of 49 years, were not hospitalised during their acute COVID infection and had mild illnesses for the most part. Several received medical intervention and support at home from paramedics and doctors. Prior to developing COVID-19, 92.4% were in employment. Participants were interviewed on average 351.7 days (11.7 months) following the onset of their COVID symptoms. All participants completed a series of 12 language tasks that were administered online. These tasks examined verbal recall (immediate and delayed), verbal

Table 1
Frequency of communication problems in 973 adults with Long COVID.

Communication problem	Frequency (%)
I struggle to find words	93.1%
I forget what I wanted to say	90.9%
I lose concentration easily when talking to others	89.6%
I mix words up and produce incorrect words	72.4%
I cannot recall what has been said earlier in conversation	65.4%
I find reading difficult	61.7%
I cannot recall what has been said in conversation after it has taken place	60.6%
I find writing difficult	51.2%
I veer off topic in conversation and cannot get back	50.8%
I struggle to produce utterances and sentences	46.6%
I struggle to understand what people are saying	38.2%

fluency (category and letter), sentence generation, confrontation naming and discourse production. There were five discourse production tasks used in the study. These tasks examined picture description (one task), procedural discourse (two tasks), and narration of different complexity (two tasks).

The performance of participants with Long COVID and brain fog in the study was significantly weaker than that of healthy participants in three areas: verbal recall; verbal fluency; and discourse informativeness. This pattern of weak performance was maintained relative to adults with COVID-19 who had no brain fog in verbal recall (immediate and delayed), letter fluency, and Cinderella narration. A group of adults with chronic fatigue syndrome was included in the study to control for the effects of debilitating fatigue on language and cognition. Relative to these adults, adults with Long COVID and brain fog also had significantly poorer performance in the areas of immediate and delayed verbal recall and Cinderella narration. Against this poor performance in verbal recall, verbal fluency, and the informativeness of spoken discourse, adults with Long COVID and brain fog performed comparably to healthy participants on tasks examining sentence generation and confrontation naming. It was concluded that adults with Long COVID and brain fog retained the ability to produce well-formed, meaningful language. But they were unable to leverage their structural language skills to produce *informative* discourse on account of underlying cognitive processing problems. This study and its findings form the background to the current investigation.

A follow-up study was conducted 6 months after this study to address several questions. First, because Long COVID is a relatively new condition with a still uncertain course, cognitive-linguistic outcomes beyond the first year are yet to be established (recall that the adults in the first study were tested, on average, 11.7 months after the onset of COVID symptoms). The follow-up study aimed to address the question: Do adults with Long COVID and brain fog still exhibit significant cognitive-linguistic problems 6 months after their first assessment? Second, the average age of adults with conditions like stroke and dementia in the caseloads of speech-language pathologists far exceeds the average age of adults with Long COVID. Most adults with Long COVID in the first study were of working age and were economically active prior to the onset of their COVID illness. The follow-up study aimed to address the question: Were adults with Long COVID and brain fog who were employed prior to their COVID illness able to recover sufficiently at 6-month follow-up to return to their pre-COVID occupational roles? Third, if the answers to these questions are that cognitive-linguistic difficulties persist well beyond the first year post COVID onset and that these adults are unable to return to work on account of their COVID-related difficulties, then what implications does this have for the provision of speech-language pathology services to these adults and for the management of these individuals by occupational health and human resource professionals?

3. Follow-up study

3.1. Participant characteristics

A total of 41 adults from the study reported in Cummings (2023a) were tested again at 6 months after their first assessment. The age, gender, education, and test status of these adults at follow-up are displayed in Table 2. This table also shows the time since COVID onset which was 625 days (20.8 months) on average. The only basis on which these adults were selected for participation in the follow-up study was their willingness and availability to undertake further testing at exactly 6 months after the date of their first assessment. Several participants from the first study were invited to participate in the follow-up study but declined because of a severe deterioration in their Long COVID condition. The 26 healthy (non-COVID) participants who participated in the first study were invited to participate in the follow-up study. However, only 11 of them qualified to take part as the remaining 15 participants developed COVID-19 between the first study and the follow-up study. Replacements for the 15 participants who contracted COVID-19 and could not take part in the follow-up study were matched as closely as possible to the original participants on age, gender, and education, The age, gender, and education of the 26 healthy participants in the first study and in the follow-up study are displayed in Table 3. The four groups of participants in the study are categorised as follows: COVID participants at Time 1 (FirstCovid), COVID participants at Time 2 (SecCovid), healthy participants at Time 1 (FirstHealthy), and healthy participants at Time 2 (SecHealthy).

Table 3
Characteristics of healthy participants.

First study		
Age	Mean: 48.2 years (SD ± 12.3 years)	Range: 18.1 – 64.6 years
Gender	Male: 10	Female: 16
Education	Under 17 years: 7	Over 17 years: 19
Follow-up study		
Age	Mean: 48.3 years (SD ± 12.4 years)	Range: 26.6 – 64.3 years
Gender	Male: 8	Female: 18
Education	Under 17 years: 6	Over 17 years: 20

3.2. Ethics approval, recruitment, and test administration

The study received ethics approval of the Human Subjects Ethics Sub-Committee of the Hong Kong Polytechnic University. Participants were sent an information sheet about the study and were asked to sign a consent form. All participants were able to give informed consent. Recruitment to the follow-up study took two forms. Healthy individuals and individuals with Long COVID who participated in the first study were invited to participate in the follow-up study. For new participants – replacements of healthy participants in the first study who had gone on to develop COVID-19 – recruitment was conducted through personal recommendations and via posts on social media groups. All tasks were administered online either through Zoom (mostly) or Skype. All participants resided in the UK and Ireland. They were asked to select a time of day that was convenient to them and that permitted participants with Long COVID to take their usual rest periods. Test sessions were conducted in 45–60 min and were recorded using two digital voice recorders (Sony ICD-UX560F) and the record function on Zoom and Skype. All audio recordings were sent to an experienced transcriber for detailed orthographic transcription.

Table 2
Characteristics of 41 participants with Long COVID at 6-month follow-up study.

Characteristic		Time since onset and test status	
Age	Average: 48.8 years (SD ± 9.1years) Range: 18.7–61.6 years	**Time since onset**	Average: 625 days (20.8 months) Range: 204 days (6.8 months) to 955 days (31.8 months)
Gender	Male: 3 (7.32%) Female: 38 (92.68%)	**Test status**	Clinical diagnosis: 19 (46.34%) PCR test: 16 (39.02%)
Education	Under 17 years: 15 (36.59%) Over 17 years: 26 (63.41%)		Antibody test: 5 (12.20%) PCR+ Antibody: 1 (2.44%)

3.3. Test materials

As an incentive to participate in the first study, all participants with Long COVID received a detailed report summarizing their performance in each language task. However, this made it difficult to use exactly the same test materials in the follow-up study. A second set of test materials was developed, with tasks matching as closely as possible the format, content and difficulty level of the tasks used in the first study. It was expected that any differences in task difficulty would be reflected in the performance of healthy participants in the follow-up study. If healthy participants performed to the same level of accuracy on both sets of test materials, it could reasonably be assumed that these tasks were of comparable difficulty. Statistical analysis showed that this assumption was well founded. There were no statistically significant differences in test performance of healthy participants on the two sets of test materials on all but four of the 12 language tasks: picture description ($M = 7.60$ for FirstHealthy, $M = 9.86$ for SecHealthy, $M_{diff} = -2.26$, $SE = 0.38$, $p < 0.001$; see Box 1 in appendix); horseshoe incident narration ($M = 13.74$ for FirstHealthy, $M = 11.67$ for SecHealthy, $M_{diff} = 2.08$, $SE = 0.75$, $p = 0.038$; see Box 1 in appendix); category fluency for fruits ($M = 25.09$ for FirstHealthy, $M = 17.46$ for SecHealthy, $M_{diff} = 7.63$, $SE = 1.32$, $p < 0.001$; see Box 1 in appendix); and Little Red Riding Hood narration ($M = 31.93$ for FirstHealthy, $M = 25.71$ for SecHealthy, $M_{diff} = 6.22$, $SE = 1.77$, $p = 0.004$; see Box 1 in appendix). To accommodate differences in task difficulty, comparisons involving these four tests were limited to those between participants with Long COVID and healthy participants at Time 2 only. Table 4 displays the tasks that were used in the follow-up study.

3.4. Statistical analysis

Data were entered into and analyzed using SPSS version 23 for Windows (IBM Corp., Armonk, NY). Descriptive statistics (for continuous variables) and frequency tables (for categorical variables) were used to summarize the data.

General linear models (GLM) (Kutner et al., 2005) were used to determine the effects of group (a categorical variable with four levels: FirstCovid, SecCovid, FirstHealthy, and SecHealthy), gender (a categorical variable with two levels: male vs. female), age (a continuous variable), and education level (a categorical variable with two levels: under 17 years vs. over 17 years) on performance of the 12 language tasks. The dependent variables were the scores of Test 1, Test 2, …, and Test 12, and the independent variables were group, gender, age, and education level. Pairwise comparisons for group were performed to compare between groups, with p-value adjusted using the Bonferroni method (Kutner et al., 2005). For categorical independent variables, estimated marginal means and the associated standard error were reported. Estimated marginal mean of a factor is the mean response of the factor after adjusting for any other variables in the model.

Pearson's correlation coefficients were used to determine if there was any correlation between phonemic (letter) fluency (Test 5) and discourse performance (Test 2, Test 4, and Test 8). For any test, with any specifications, a p-value less than 0.05 indicated statistical significance.

The following model assumptions of general linear models (Kutner et al., 2005) were checked:

- Independence: residuals are independent (checked by Durbin-Watson statistic).
- Linearity: linearity of the regression function (checked by residual plot (i.e., plotting residuals against fitted values)).
- Normality: the distribution of residuals is normal (checked by the quantile-quantile (QQ) plot and the Shapiro-Wilk test).
- Homoscedasticity: the residuals have constant/equal variance (checked by residual plot (i.e., plotting residuals against fitted values) and Levene's test).

Table 4
Tasks and instructions to participants.

Task	Instruction
Test 1: Immediate recall	A 100-word story entitled "Summer Fete" was read aloud to each participant who was then asked to recall it immediately. *Instruction:* "I'm going to tell you a short story. I want you to listen to it carefully. I will then ask you to tell it back to me."
Test 2: Picture description	This is the picture description task from the Western Aphasia Battery-Revised (Kertesz, 2006). Participants were asked to describe a black-and-white line drawing of a picnic scene while viewing the image. *Instruction:* "Here is a picture I would like you to look at. Tell me everything you see going on in this picture."
Test 3: Sentence generation	Participants are auditorily presented with two, three, and four words and are asked to generate a brief sentence. *Instruction:* "I'm going to give you words and I want you to put them in a brief sentence. Do not worry about the order of the words. You can use the words in any order."
Test 4: Horseshoe Incident narration	Participants are shown six, black-and-white line drawings in sequence and are asked to tell a story based on the pictures. *Instruction:* "Here are six pictures. Please take a couple of minutes to look at each of them. I am then going to ask you to tell a story based on the pictures."
Test 5: Phonemic (letter) fluency	Participants are asked to generate words beginning with the letters C, F, and L in 60 s. *Instruction:* "Tell me as many words as possible that begin with the letter 'C'. Do not use names like *Charles* and *Christina* and multiple words with the same stem but different endings like *cost, costly, costliness*. You have 60 s. I will start the stopwatch as soon as you give me the first word with 'C'."
Test 6: Semantic (category) fluency 1	Participants are asked to generate the names of fruits in 60 s. *Instruction:* "Tell me as many names of fruits as possible. You have 60 s. I will start the stopwatch as soon as you give me the first name of a fruit."
Test 7: Semantic (category) fluency 2	Participants are asked to generate the names of vehicles in 60 s. *Instruction:* "Tell me as many names of vehicles as possible. You have 60 s. I will start the stopwatch as soon as you give me the first name of a vehicle."
Test 8: Little Red Riding Hood narration	Participants are shown a wordless picture book of the Little Red Riding Hood story. The book is then closed, and participants are asked to narrate the story. *Instruction:* "I'm sure you are familiar with the story of Little Red Riding Hood. I am going to use these pictures to refresh your memory of the story. I will scroll down the pictures and stop at each one. If you are happy with a picture, just say "okay". If you need me to explain how the picture relates to the story, please let me know. When we get to the end of the pictures, I am going to ask you to tell me the full Little Red Riding Hood story."
Test 9: Procedural discourse 1	Participants are asked to describe the steps that someone would go through to machine wash a load of laundry. *Instruction:* "Can you talk me through all the steps or stages needed to machine wash a load of laundry?"
Test 10: Procedural discourse 2	Participants are asked to describe the steps that someone would go through to make a cup of coffee. *Instruction:* "Can you talk me through all the steps or stages needed to make a cup of coffee?"
Test 11: Confrontation naming	Participants are shown 20 black-and-white line drawings of objects and animals and are asked to name them. *Instruction:* "I'm going to give you a number and I would like you to give me the name of the thing next to it."
Test 12: Delayed recall	Participants are asked to recall the 100-word story (Summer Fete) that was read aloud to them at the

(*continued on next page*)

Table 4 (*continued*)

Task	Instruction
	beginning of the session. *Instruction:* "I told you a short story at the start of the session. Can you tell me that story back again now?"

The following assumptions of Pearson's correlation coefficients (Moore et al., 2009) needed to be satisfied:

- The variables are continuous (satisfied as the test scores were continuous).
- The relationship between the two variables needs to be linear (checked by plotting one variable against the other variable).
- Both variables are normally distributed (checked using the QQ plot and the Shapiro-Wilk test).

If the normality assumption and/or the assumption of homoscedasticity was not satisfied, the analysis results of GLM and Pearson's correlation were still retained and the robustness of the parametric approach (i.e., GLM and Pearson's correlation) was to be confirmed using the bootstrap approach in SPSS version 23. The bootstrap technique involves repeatedly resampling the sample, which then enables application of statistical inference without distributional assumptions, such as homoscedasticity and normality (Lavrakas, 2008). The bootstrap technique is recommended for testing of results of parametric statistical tests when model assumptions of the parametric tests are not satisfied (Lavrakas, 2008). If the linearity assumption was not satisfied, transformation of the variables (or adding interaction/quadratic terms (for GLM only)) may be employed. If the independence assumption was not satisfied, lags of the dependent variable and/or lags of some of the independent variables may be included in the GLM to fix the issue.

3.5. Results

Performance across all 12 language tasks was analysed (see Box 2 in appendix). FirstCovid participants had the lowest average scores for seven tests (Tests 1, 2, 3, 5, 10, 11, and 12) and SecCovid participants had the lowest average scores for four tests (Tests 4, 6, 7, and 8). FirstHealthy participants had the highest average scores for eight tests (Tests 3, 4, 5, 6, 7, 8, 9, and 12) and SecHealthy participants had the highest average scores for three tests (Tests 1, 2, and 11). SecCovid participants had the highest average score for Test 10 and SecHealthy participants had the lowest average score for Test 9. Fig. 1 displays the mean scores of the 12 language tasks by group.

The effects of age, gender, and education level on performance in the 12 language tasks were examined. The age effect was statistically significant in the performance of Test 1 ($F(1, 127) = 5.456$, $p = 0.021$), Test 2 ($F(1, 126) = 10.938$, $p = 0.001$), Test 4 ($F(1, 127) = 12.835$, $p < 0.001$), and Test 12 ($F(1, 127) = 8.782$, $p = 0.004$) (Box 3). Upon examining the parameter estimates of age (Box 4), it was concluded that there was a statistically significantly negative age effect in the performance of Test 1 ($\beta = -0.003$, SE $= 0.001$) and Test 12 ($\beta = -0.004$, SE $= 0.001$). That is, older participants tended to have lower test scores for Test 1 (immediate recall) and Test 12 (delayed recall). It was also concluded that there was a statistically significantly positive age effect in the performance of Test 2 ($\beta = 0.003$, SE $= 0.001$) and Test 4 ($\beta = 0.007$, SE $= 0.002$). That is, older participants tended to have higher test scores for Test 2 (picture description) and Test 4 (Horseshoe Incident narration).

The age effect was not statistically significant in the performance of Test 3 ($F(1, 127) = 0.237$, $p = 0.627$), Test 5 ($F(1, 126) = 3.359$, $p = 0.069$), Test 6 ($F(1, 127) = 0.485$, $p = 0.487$), Test 7 ($F(1, 127) = 0.553$, $p = 0.458$), Test 8 ($F(1, 127) = 1.154$, $p = 0.285$), Test 9 ($F(1, 127) = 1.404$, $p = 0.238$), Test 10 ($F(1, 126) = 0.141$, $p = 0.708$), and Test 11 ($F(1, 127) = 1.402$, $p = 0.239$) (Box 3).

The gender effect in each of the GLM was also examined. The gender effect was not statistically significant in the performance of Test 1 ($F(1, 127) = 1.673$, $p = 0.198$), Test 2 ($F(1, 126) = 0.836$, $p = 0.362$), Test 3 ($F(1, 127) = 0.537$, $p = 0.465$), Test 4 ($F(1, 127) = 0.202$, $p = 0.654$), Test 5 ($F(1, 126) = 0.780$, $p = 0.379$), Test 6 ($F(1, 127) = 0.658$, $p = 0.419$), Test 7 ($F(1, 127) = 0.585$, $p = 0.446$), Test 8 ($F(1, 127) = 0.231$, $p = 0.632$), Test 9 ($F(1, 127) = 0.455$, $p = 0.501$), Test 10 ($F(1, 126) = 0.136$, $p = 0.713$), Test 11 ($F(1, 127) = 0.079$, $p = 0.779$), and Test 12 ($F(1, 127) = 0.964$, $p = 0.328$) (Box 3). The estimated marginal means for gender are presented in Box 5 and displayed in Box 6 in appendix.

The education effect in each of the GLM was examined. The education effect was statistically significant in the performance of Test 2 (F(1,

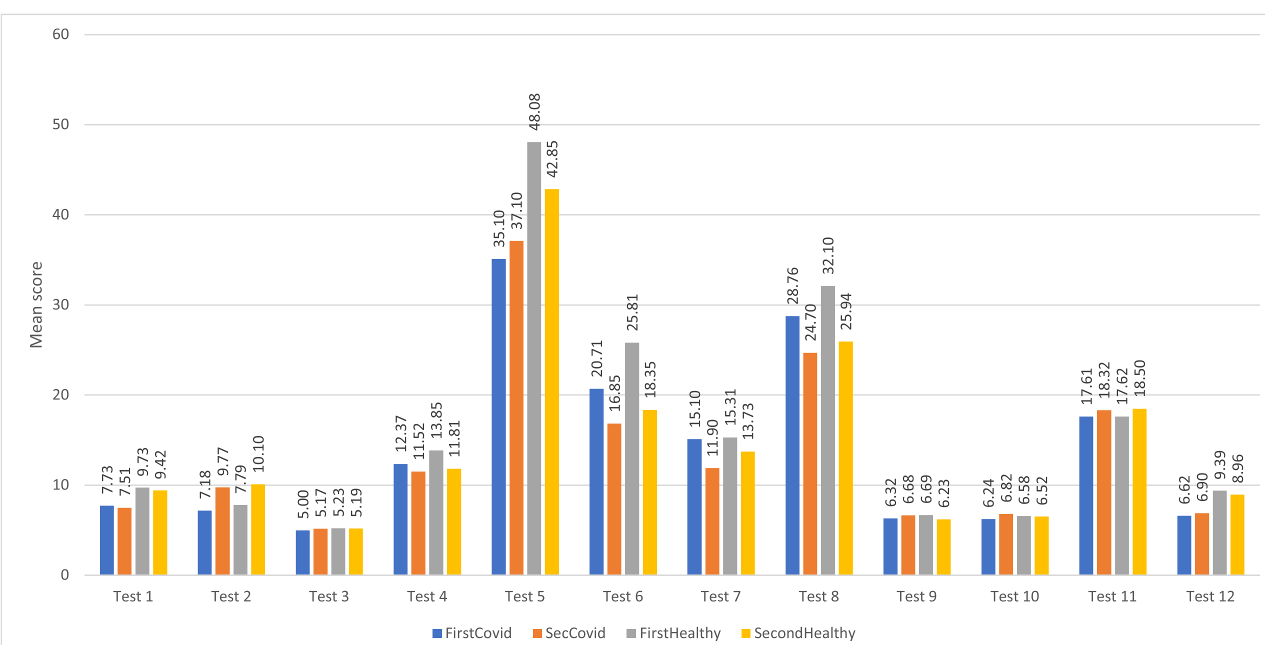

Fig. 1. Performance of participants in the 12 language task.

126) = 6.779, p = 0.010), Test 3 (F(1, 127) = 6.331, p = 0.013), Test 6 (F(1, 127) = 8.479, p = 0.004), Test 7 (F(1, 127) = 5.358, p = 0.022), and Test 11 (F(1, 127) = 5.908, p = 0.016) (Box 3). Upon checking the estimated marginal means for education (Box 5 and Box 7), it was concluded that participants with over 17 years of education had statistically significantly higher scores in picture description in Test 2 (M = 8.15, SE = 0.23 for under 17 years; M = 8.82, SE = 0.18 for over 17 years), sentence generation in Test 3 (M = 4.81, SE = 0.15 for under 17 years; M = 5.23, SE = 0.12 for over 17 years), category fluency 1 in Test 6 (M = 18.35, SE = 0.80 for under 17 years; M = 20.95, SE = 0.62 for over 17 years), category fluency 2 in Test 7 (M = 12.71, SE = 0.62 for under 17 years; M = 14.30, SE = 0.48 for over 17 years), and confrontation naming in Test 11 (M = 17.41, SE = 0.30 for under 17 years; M = 18.23, SE = 0.23 for over 17 years) than participants with under 17 years of education.

The education effect was not statistically significant in the performance of Test 1 (F(1, 127) = 0.015, p = 0.902), Test 4 (F(1, 127) = 0.476, p = 0.492), Test 5 (F(1, 126) = 1.544, p = 0.216), Test 8 (F(1, 127) = 0.056, p = 0.813), Test 9 (F(1, 127) = 2.771, p = 0.098), Test 10 (F(1, 126) = 0.846, p = 0.359), and Test 12 (F(1, 127) = 0.002, p = 0.963) (Box 3).

In terms of group comparisons between SecCovid and SecHealthy, there was a statistically significant difference in language task performance between SecCovid and SecHealthy on immediate recall in Test 1 (M = 7.26 for SecCovid, M = 9.31 for SecHealthy, $M_{diff} = -2.05$, SE = 0.52, p = 0.001; Box 1 and Box 5). There was also a statistically significant difference in language task performance between SecCovid and SecHealthy on delayed recall in Test 12 (M = 6.71 for SecCovid, M = 8.86 for SecHealthy, $M_{diff} = -2.16$, SE = 0.54, p = 0.001; Box 1 and Box 5). There were no statistically significant differences between SecCovid and SecHealthy on any of the other language tasks.

There were statistically significant differences between FirstCovid and SecCovid on four tests: picture description in Test 2 (M = 6.96 for FirstCovid, M = 9.53 for SecCovid, $M_{diff} = -2.57$, SE = 0.31, p < 0.001; Box 1 and Box 5); category fluency 1 in Test 6 (M = 19.95 for FirstCovid, M = 16.11 for SecCovid, $M_{diff} = 3.84$, SE = 1.05, p = 0.002; Box 1 and Box5); category fluency 2 in Test 7 (M = 14.59 for FirstCovid, M = 11.39 for SecCovid, $M_{diff} = 3.21$, SE = 0.81, p = 0.001; Box 1 and Box 5); and complex narration in Test 8 (M = 28.38 for FirstCovid, M = 24.35 for SecCovid, $M_{diff} = 4.03$, SE = 1.40, p = 0.029; Box 1 and Box 5). There were no statistically significant differences between FirstCovid and SecCovid on any of the other tasks.

The performance of FirstHealthy and SecHealthy on the 12 language tasks was also compared. There were statistically significant differences between FirstHealtjy and SecHealthy on four tests: picture description in Test 2 (M = 7.60 for FirstHealthy, M = 9.86 for SecHealthy, $M_{diff} = -2.26$, SE = 0.38, p < 0.001; Box 1 and Box 5); narration based on six pictures in Test 4 (M = 13.74 for FirstHealthy, M = 11.67 for SecHealthy, $M_{diff} = 2.08$, SE = 0.75, p = 0.038; Box 1 and Box 5); category fluency 1 in Test 6 (M = 25.09 for FirstHealthy, M = 17.46 for SecHealthy, $M_{diff} = 7.63$, SE = 1.32, p < 0.001; Box 1 and Box 5); and complex narration in Test 8 (M = 31.93 for FirstHealthy, M = 25.71 for SecHealthy, $M_{diff} = 6.22$, SE = 1.77, p = 0.004; Box 1 and Box 5). There were no statistically significant differences between FirstHealthy and SecHealthy on any of the other tasks.

To investigate if there was a relationship between phonemic (letter) fluency (Test 5) and discourse performance (Test 2, Test, 4, Test 8), Pearson's correlation coefficients were calculated (Box 8). Overall, there was a statistically significantly positive relationship between Test 5 and Test 2 (r = 0.180, p = 0.039) and between Test 5 and Test 4 (r = 0.243, p = 0.005). However, there was no statistically significant relationship between Test 5 and Test 8 (r = 0.114, p = 0.191) (Box 9).

When examining only the FirstCovid group, there was a statistically significant positive relationship between Test 5 and Test 4 (r = 0.340, p = 0.029). However, there was no statistically significant relationship between Test 5 and Test 2 (r = 0.247, p = 0.124) and between Test 5 and Test 8 (r = 0.017, p = 0.917) (Box 10). When examining only the SecCovid group, there was a statistically significant positive relationship between Test 5 and Test 2 (r = 0.408, p = 0.008) and between Test 5 and Test 4 (r = 0.321, p = 0.040). However, there was no statistically significant relationship between Test 5 and Test 8 (r = 0.102, p = 0.528). When examining only the FirstHealthy group, there was no statistically significant relationship between Test 5 and Test 2 (r = 0.220, p = 0.291), between Test 5 and Test 4 (r = 0.106, p = 0.615), and between Test 5 and Test 8 (r = −0.052, p = 0.805). When examining only the SecHealthy group, there was no statistically significant relationship between Test 5 and Test 2 (r = −0.069, p = 0.739), between Test 5 and Test 4 (r = −0.247, p = 0.223), and between Test 5 and Test 8 (r = 0.015, p = 0.941).

4. Discussion

In summary, adults with Long COVID displayed significantly weaker performance than healthy adults in immediate and delayed verbal recall at the 6-month follow-up study. This was consistent with their poor performance in verbal recall in the first study and indicated that this area of cognitive-linguistic performance had not improved during the 6-month period between the first and follow-up studies. The absence of statistically significant differences between adults with Long COVID and healthy adults on all other language tasks indicated that adults with Long COVID had improved their performance in several areas that were weak in the first study. These areas are verbal fluency (letter and category fluency) and discourse informativeness. The fact that adults with Long COVID had effectively closed the gap between their performance and that of healthy adults in verbal fluency and discourse informativeness suggested that there had been some spontaneous improvement in these cognitive-linguistic skills in the 6 months between the first and follow-up studies.

These findings are also supported by comparing the performance of adults with Long COVID at the first study and the follow-up study. There were no statistically significant differences on immediate and delayed verbal recall between first and follow-up studies in adults with Long COVID, indicating that there had been no improvement in this area of performance. Moreover, we can be certain that the verbal recall tasks used in these studies were of comparable difficulty given that healthy adults displayed no statistically significant differences between their performance on these tasks at the first and follow-up studies. So, the lack of change in adults with Long COVID reflected a lack of improvement in their verbal recall skills rather than any variation in task difficulty – it was not the case that their verbal recall skills had improved but that the verbal recall task on follow-up was significantly more difficult to perform and was, therefore, unable to reveal this improvement.

The informativeness of spoken discourse was examined through three tasks: Test 2 (picture description); Test 4 (narration based on six pictures); and Test 8 (complex narration based on a fictional story). The performance of healthy adults on these tasks at follow-up suggested that they varied in difficulty relative to the tasks used in the first study. Picture description was significantly easier at follow-up while narration based on six pictures and complex narration were significantly harder. Notwithstanding these differences in task difficulty, adults with Long COVID matched the discourse performance of healthy adults on all three tasks at follow-up. The reduced informativeness that had been a feature of these adults' performance on these tasks in the first study had effectively resolved by the time of the follow-up study. We will see below, however, that this finding still masked some significant discourse difficulties in these adults.

To the extent that the discourse performance of adults with Long COVID had improved at 6-month follow-up, it is interesting to consider what factor(s) may have contributed to this improvement. Letter fluency is a measure of executive functioning that has been found to correlate with narrative discourse performance in adults with a range of acquired neurological disorders (Ash et al., 2011; Ash et al., 2014). In the follow-up study, there was a statistically significant positive relationship in adults with Long COVID between letter fluency (Test 5) and two discourse production tasks: picture description (Test 2) and narration based on six pictures (Test 4). Moreover, adults with Long COVID matched the letter fluency performance of healthy adults at follow-up. This represented an improvement in letter fluency which had been an area of depressed performance for adults with Long COVID in the first study. These factors combined suggest that gains made by adults with Long COVID in the informativeness of spoken discourse at 6-month follow-up were likely attributable to improvements in executive functioning.

At follow-up, adults with Long COVID performed as a group similarly to healthy adults on discourse production tasks. However, this group performance nevertheless masked difficulty on discourse tasks of several adults with Long COVID. For some adults, complex narration based on the fictional story Little Red Riding Hood was particularly challenging. These narratives often displayed reduced informativeness. Some information was simply omitted while other information was conveyed in the wrong order. The narrative below was produced by a 55-year-old woman ('CL') who was 14.6 months post COVID onset at the time of her follow-up assessment. CL's narrative achieved an informativeness score of 16 out of 50. This score placed CL's performance between 1 and 2 standard deviations below the mean score of both adults with Long COVID and healthy adults on the same task:

1: Little Red Riding Hood making a cake for with her mother because her grandmother isn't

2: well (.) um they put it in a basket her mother tells her goodbye she starts to she's walking

3: away and she sees something um she sees beautiful flowers that she starts to pick for her

4: grandmother and then a wolf behind a tree sees her and realises that she's going to her

5: grandmother's house so the wolf goes in (.) I thought he killed the grandmother in the real

6: story but in this one he gets in the bed puts on the grandmother's clothes an um Little Red

7: Riding Hood knocks on the door and comes in and she's saying my what teeth big teeth

8: you have my what (.) um (1.71) big hands you have the wolf eats the cake and she realises

9: it's a wolf and then um (.) somehow the grandmother she and the grandmother escape

10: together and the grandmother is talking to her on a bench at the end.

In line 4, CL omits the exchange between the wolf and Little Red Riding Hood where the wolf asks Red Riding Hood what she is doing (*picking flowers for grandmother*) and where she is going (*to grandmother's house*). The omission of this information forces the hearer to make an inferential leap in order to assimilate the presupposition of the factive verb "realises" – namely, that Red Riding Hood *is* going to her grandmother's house. Almost immediately after omitting the exchange between the wolf and Little Red Riding Hood, CL omits the wolf's action of running ahead of Red Riding Hood in order to arrive at grandmother's cottage before her. There is no account given of what happens to the grandmother other than she is not killed by the wolf as happens in "the real story". Another informational gap occurs when CL goes straight from stating that Red Riding Hood enters the cottage to saying, "what big teeth you have". Two actions should be related by the speaker – the cake and flowers are handed to grandmother (who is actually the wolf) and the wolf devours the cake. It occurs late to CL that these actions have been omitted and she then states the second of them, "the wolf eats the cake", out of sequence. Finally, at the end of the narrative, there is no attempt made by CL to address the moral of the story, namely, that you should never talk to strangers. Rather, Red Riding Hood and her grandmother are simply represented as talking together while they sit on a bench.

CL's reduced informativeness during the production of spoken discourse is not related to any deficit in her structural language skills. She was able to produce well-formed, meaningful language that contains a range of grammatical constructions and an appropriate vocabulary for her educational level and professional background – CL was a masters-qualified professional writer and health coach before her COVID illness. Notwithstanding her strong structural language skills, CL was unable to leverage these skills to produce *informative* discourse. In Cummings (2023a), it was argued that we need to look beyond an aphasic language disorder in order to explain language difficulties of adults with Long COVID. (It should be noted, however, that individuals with severe COVID disease can develop aphasia as a neurological complication of the infection.) Given the cognitive basis of COVID-related language difficulties, it was contended that these difficulties are most appropriately diagnosed as a *cognitive-communication disorder* within a wider nosology of language disorder.

At follow-up, adults with Long COVID performed similarly to healthy adults on tasks that assessed structural language skills. These tasks include Test 3 which examines sentence generation and Test 11 which assesses confrontation naming. These same language skills were also intact in adults with Long COVID in the first study. But normal test scores in sentence generation and confrontation naming often masked considerable cognitive struggle and inefficiency on the part of these adults. Below, a 56-year-old woman ('LL') with Long COVID is attempting to name pictures during the confrontation naming task in the follow-up study. LL was a primary school teacher prior to her COVID illness. She was 14.3 months post COVID onset at the time of her second assessment. Although LL named 17 of 20 items correctly – a score that placed her performance just below the mean score of 18.5 in healthy adults in the follow-up study – she displayed considerable inefficiency during her naming of several test items (see Table 5).

Although LL named all five target words in Table 5 correctly, three without prompts, several behaviours indicated that her lexical access and retrieval were compromised by cognitive inefficiencies. First, lengthy timed pauses occurred throughout LL's responses. These pauses gave LL more time in which to access and search her mental lexicon; they were an adaptive strategy to compensate for slow information processing. Second, the examiner's use of phonemic cues facilitated LL's naming of the words *chisel* and *cannon*. The provision of these sound cues provided LL with the additional activation that was required to trigger the production of these words. Third, LL talked around the target word *cannon* (e.g., "I know these are shot [...] with the Queen and it's her birthday"). So-called circumlocution helps LL achieve additional activation of the target word so that the threshold for naming can be reached. Fourth, LL produced expressions of frustration (e.g., *ah God*) and statements that conveyed her struggle during naming (e.g., *I can't*

Table 5
LL's responses during confrontation naming.

Target word	LL's response
Chisel	"um (2.67) God I can't think what it's called (10.97) I know it's not a screwdriver (9.21) I can't think what it's called I know what it does [*Examiner:* would you like me to give you the first sound of the word?] yeah [*Examiner:* che, che] oh, a chisel"
Artichoke	"ah (4.15) can't think what it's called um (2.50) a choke (1.64) what's it called (2.29) something choke (1.71) artichoke"
Crescent	"oh what's it called (.) um I do know it (2.01) I do know it number one hundred and forty-six is a (3.52) crescent moon"
Pliers	"ah God um a hundred and seventy-six (3.71) not a spanner um (2.96) pliers"
Cannon	"forty-five is a (1.87) what is it (4.87) I know these are shot when it's um something that the (1.06) with the Queen and it's her birthday (2.28) I can't think what it's called (2.40) [*Examiner:* would you like me to give you the first sound?] yes please [*Examiner:* ca, ca] (.) a cannon"

Table 6
AM's responses during the sentence generation task.

Target words	AM's response
patient – ambulance	"okay um (5.54) the ambulance (.) it's like why do I find this so difficult um take your time (1.96) the [peɪʃ] the patient ah stepped into the ambulance"
volcano – erupt – lava	"okay (1.57) um (3.80) and again I am thinking about tenses again here which I think the, the erupt not erupted [*comment to examiner*] alright um (1.60) the volcano erupted and the lava came spilling out"
dead – gun – farmer – burglar	"um (3.54) farmer gun (1.93) the farmer his gun (2.13) oh farmer gun (2.36) oh eh the farmer shot his gun and the burglar (2.09) was dead"

Table 7
Pre-Covid occupation of 41 participants.

Occupation	%	Occupation	%
Healthcare (total): 13	**31.71%**	**Other occupations (total): 10**	**24.39%**
Consultant (1)	2.44%	Police officer (3)	7.32%
General practitioner (1)	2.44%	Probation service (1)	2.44%
Nurse (6)	14.63%	Project manager (1)	2.44%
Dietician (1)	2.44%	Public rights of way officer (1)	2.44%
Occupational therapist (2)	4.88%	Leadership coach/trainer (1)	2.44%
Paramedic (1)	2.44%	Human resources manager (1)	2.44%
Healthcare assistant (1)	2.44%	Shop assistant (1)	2.44%
Education (total): 13	**31.71%**	British Sign Language interpreter (1)	2.44%
Teacher (11)	26.83%	**Full-time education (1)**	**2.44%**
Lecturer (1)	2.44%	**Unemployed (4)**	**9.75%**
Schools career adviser (1)	2.44%		

think what it's called). These remarks further suggested that naming was a laboured, inefficient cognitive process for LL.

Sentence generation also posed difficulties for adults with Long COVID, even when scores on this task were in the normal range. In Table 6, a 58-year-old woman ('AM') with Long COVID is attempting to generate sentences based on combinations of two, three, and four spoken words. AM was a health care assistant before her COVID illness. She was 14.2 months post COVID onset at the time of her second assessment. Although she achieved a score of 5 out of 6 on this task – the average score of healthy adults on sentence generation in the follow-up study was 5.19 – AM's responses were laboured and inefficient (see Table 6).

Several features of AM's responses suggest that this task was particularly challenging for her. AM produced many false starts and repetitions of words and phrases as she worked her way towards her final utterance. Lengthy timed pauses and frequent use of fillers (e.g., *um, eh*) provided AM with more time in which to undertake sentence encoding. Statements such as "why do I find this so difficult" suggested that AM's subjective cognitive experience during this task was one of considerable struggle. In short, although AM's sentence generation score was comparable to that of healthy adults, her execution of the task revealed significant cognitive inefficiencies in her sentence encoding. The presence of cognitive difficulties in adults with Long COVID who have normal test performance has implications for the assessment of these adults (Cummings, 2023c). This issue is addressed in Section 5.2 below.

5. Implications

This study has far-reaching implications for a large population of adults who have had their lives upended by Long COVID. Prior to the COVID-19 pandemic, no health problem had compromised so many people of working age or in such a devastating way. The fact that problems with cognition and language should feature so prominently in the post COVID-19 condition raises pressing concerns for employers and health professionals alike. In this section, we examine the impact of COVID-related cognitive and language difficulties on the ability of adults with Long COVID to return to work. Aside from the employment issues raised by Long COVID, there are challenges for the health professionals – speech-language pathologists for the most part – who must provide clinical communication services to adults with Long COVID. This new condition raises questions relating to assessment, diagnosis and intervention that must be addressed. This section also examines these questions and considers possible answers.

5.1. Employment

This follow-up study has shown that adults with Long COVID continue to experience significant cognitive-linguistic difficulties nearly two years after the onset of their COVID illness. With difficulties of such an extended duration, it is to be expected that Long COVID has a significant impact on employment and the ability of individuals to return to work. This study also collected information on participants' pre-COVID employment and on employment outcomes at an average of 20.8 months (range = 6.8–31.8 months) after the onset of illness. Prior to their COVID illness, 90.25% of participants were either in employment or in full-time education (see Table 7). Most participants were employed in healthcare (31.71%) and education (31.71%). By the date of their second assessment, 97.3% of participants who had been in employment prior to COVID-19 had not been able to return to their full pre-COVID occupational role (see Table 8). Additionally, 69.44% had not been able to return to *any* type of employment by the date of their second assessment. In the absence of employment, participants had taken early retirement (8%), had received ill health retirement (28%), or were dependent on social security benefits (48%) for financial support (see Table 9). An altogether smaller number, just four participants (16%), had been able to return to their pre-COVID occupational role with adjustments *after* the date of their second assessment.

Of course, it may be argued that these low rates of work return could be attributed to symptoms other than cognitive-linguistic difficulties. However, when questioned about their employment outcomes at the second assessment, participants with Long COVID suggested that their cognitive-linguistic difficulties were a significant factor in their inability to return to work. A 50-year-old woman, who worked as an occupational therapist (OT) prior to developing COVID-19, described the conditions under which she had not been able to return to work:

Woman with Long COVID (23.8 months post onset):

> "I was an OT working on Rapid Response, so was seeing patients right up to 1st April 2020. I have not been able to return to work since, now medically retired. This is due to cognitive problems still including language."

Table 8
Occupational status before Covid and at 6-month follow-up study.

Occupational status	Raw number (percentage)
Were you employed before developing COVID-19?	YES: 37 (90.24%) NO: 4 (9.76%)
Had you returned to your full pre-COVID occupational role by the date of your follow-up assessment?	YES: 1/37 (2.70%) – see Note NO: 36/37 (97.30%)
Had you returned to *any* form of employment by the date of your follow-up assessment? If YES, what was this employment?	YES: 11/36 (30.56%) Pre-COVID role with adjustments: 10 New work role: 1 NO: 25/36 (69.44%)

Note: The single participant who had returned to her full pre-COVID occupational role by the date of her second assessment was the youngest participant in the study. She was in full-time education but had to change her mode of study to part-time the month after her second assessment because of Long COVID.

Table 9
Outcome for participants with no work return at 6-month follow-up study.

Outcome	Raw number (percentage)
Returned to pre-COVID role with adjustments	4/25 (16.00%)
Took early retirement	2/25 (8.00%)
Received ill health retirement	7/25 (28.00%)
Receiving social security benefits	12/25 (48.00%)

A 52-year-old woman recounted how she struggled with concentration and retention of information and was no longer able to read. She was a teacher before developing COVID-19 and had not returned to work 26.5 months after the onset of her COVID illness:

Woman with Long COVID (26.5 months post onset):

"My brain fog means that I can no longer concentrate for very long or retain information that I have read. Before Long Covid I was an avid reader, now I've given up as I can't retain the plot."

A 33-year-old woman in the study worked as a British Sign Language interpreter prior to her COVID illness. This occupational role places a high language demand on its user. Unsurprisingly, this woman's cognitive-linguistic difficulties had prevented her from returning to work. She had not been able to resume her full-time interpreting role by the date of her second assessment some 25 months after the onset of her COVID illness:

Woman with Long COVID (25.1 months post onset):

"Before Covid I worked full time. After the second assessment I was back informally yes, about 3 h a week. Not fully interpreting but modifying emails for a client I have worked with for years. I am still not on the interpreting register as I am not ready to take on bookings. But I work informally with an old client."

The question naturally arises: given that cognitive-linguistic difficulties in Long COVID have a significant occupational impact in the medium to long term, how should these difficulties be managed by employers and occupational health professionals? Standard phased returns, with work duties scaling up to a full load of duties within a relatively short period of time, are often unsuccessful for people with Long COVID. Comments from participants in the study indicate that these phased returns place considerable stress on individuals. This often leads to a resurgence of COVID symptoms and a further period of sickness absence (see Fig. 2). Below, a 50-year-old woman who worked as a senior nurse in a neonatal unit reported the type of problems that poorly planned phased returns can create for people with Long COVID. The short duration of these returns, coupled with the unpredictable nature of Long COVID symptoms, including cognitive-linguistic difficulties, made it difficult for her to approach a return to work with confidence:

Woman with Long COVID (15.3 months post onset):

"Not knowing how long my cognition and word finding will take to return is the hardest thing. Especially when work want to know when I'm fit to return and there is only 12-week return on offer. I really don't think this will be feasible, with the position and responsibilities I have, to get back to full time in that time span."

People with Long COVID often experience inflexibility and a lack of support at the hands of their employers. It was not uncommon for requests for adjustments to be denied, even when they represented a continuation of a pattern of working that was already successfully in use (e.g., working from home one day a week). Some redeployments caused anxiety and frustration as people with Long COVID knew "normal redeployments" were certain to fail. Human resources departments exacerbated the distress of people with Long COVID through poor communication, insensitive interactions, and confrontational workplace meetings. Participants with Long COVID in the study reported having to return to work for fear of dismissal by their employers. Equally distressing were reports of participants having to present for work when they were clearly too unwell to do so (see Fig. 2).

Clearly, some people with Long COVID *are* successful in returning to work and there is much that we can learn from these cases. Participants in the follow-up study described the conditions that had facilitated their return to work (see Fig. 3). The duration and intensity of phased returns were important considerations. Phased returns that were planned over many months rather than a few weeks were more likely to secure a good

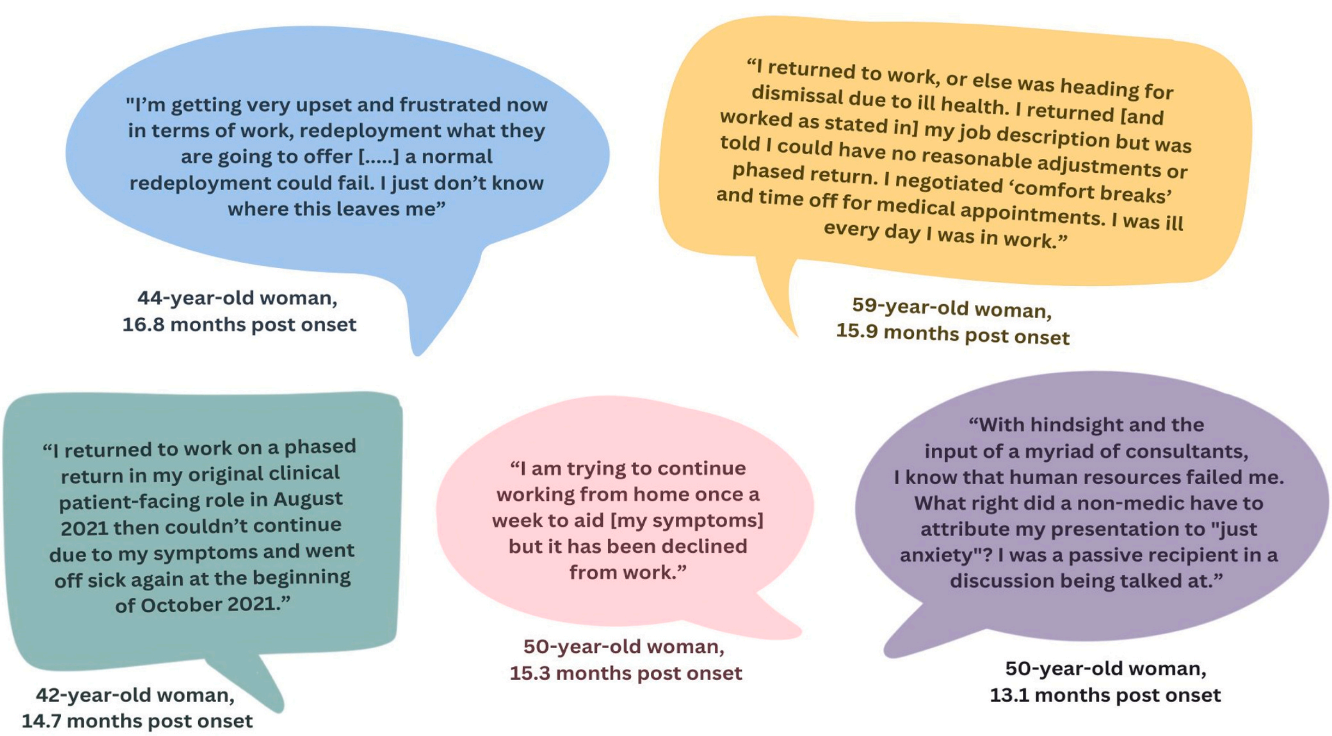

Fig. 2. Negative occupational experiences of adults with Long COVID at follow-up.

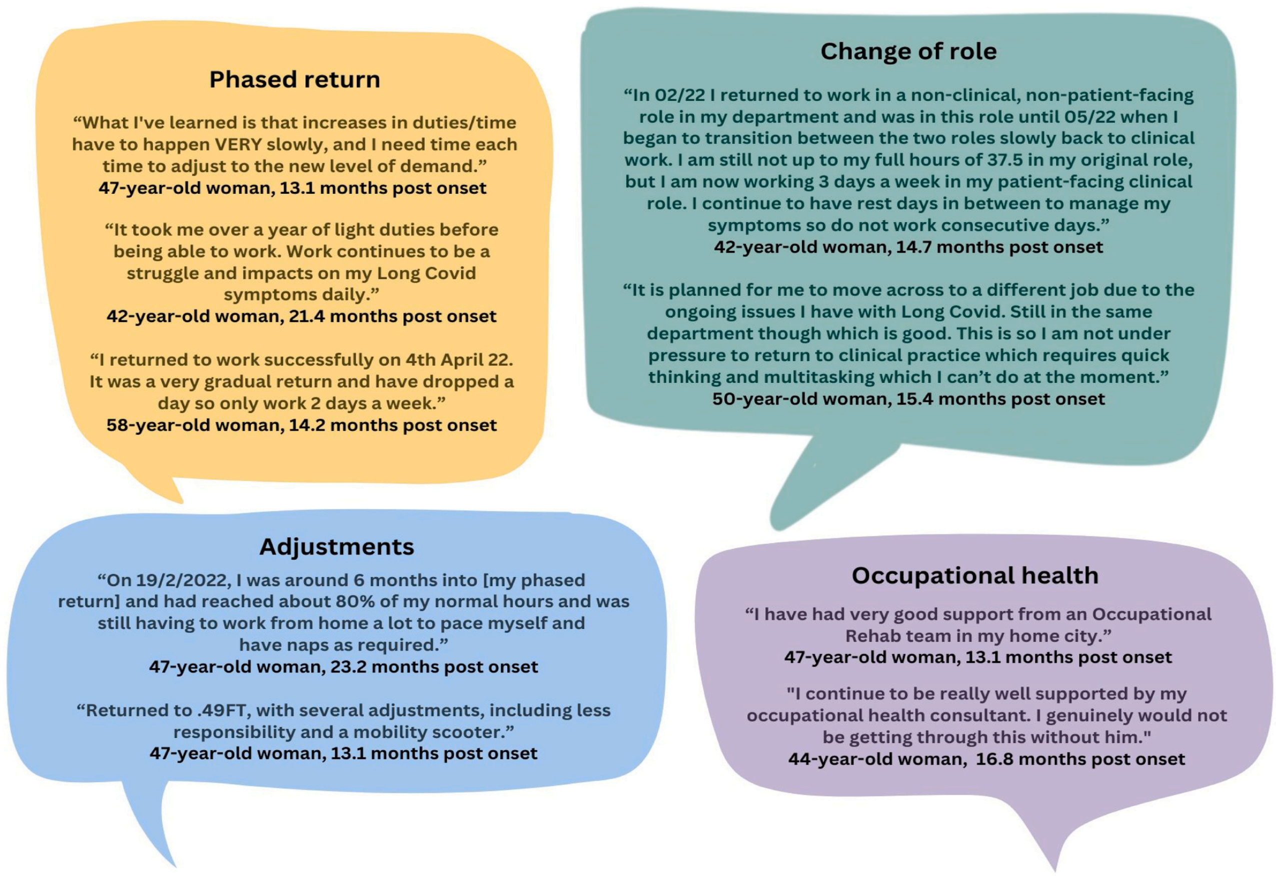

Fig. 3. Factors that facilitate a return to work in adults with Long COVID.

outcome for people with Long COVID. Also, duties and tasks that were increased gradually, with extended periods of time in between each new responsibility, also helped adults with Long COVID to make a permanent return to work. A change of work role was also reported to be beneficial. Several participants in the follow-up study were employed in health roles that placed high demands on cognition and communication. They were redeployed in non-clinical roles that gave them time to regain their physical and mental stamina in the workplace without the risk that patients might come to harm. Adjustments that involved the provision of equipment (e.g., mobility scooter) and flexible work arrangements (e.g., working from home and on alternative days) also enabled adults with Long COVID to return to the workplace and remain in it. Finally, several participants in the follow-up study acknowledged the excellent support they received from occupational health professionals in preparing them to return to work and supporting them as they adjusted to their work roles.

5.2. Speech-language pathology

Cognitive-linguistic difficulties in Long COVID have clinical implications for the health professionals – speech-language pathologists for the most part – who must assess and treat these difficulties. The performance of adults with Long COVID in the follow-up study reaffirms that there is little to be gained in assessing language skills in this new population of clients in the way that speech-language pathologists assess language in a condition like aphasia. Adults with Long COVID have relatively strong structural language skills – they can produce well-formed, meaningful utterances, as suggested by their performance on tasks like sentence generation and confrontation naming, and their language comprehension is adequate for understanding complex task instructions. Where adults with Long COVID experience problems is in the *use* of language to produce *informative* discourse. The high-level cognitive-linguistic processes that are pressed into use during discourse production are not successfully examined through the type of language test batteries that are used to assess aphasia. In fact, adults with Long COVID may be expected to perform in the normal range on assessments such as the *Boston Diagnostic Aphasia Examination-3* (BDAE-3; Goodglass et al., 2001) and the *Western Aphasia Battery-Revised* (WAB-R; Kertesz, 2006). (It should, of course, be acknowledged that both the BDAE-3 and the WAB-R contain a picture description task – see below.) An alternative method of assessment is required that examines aspects of language that are most susceptible to disruption in the presence of cognitive dysfunction.

This alternative method of assessment involves the use of discourse production tasks. The cognitive complexity of these tasks can be varied through simple adjustments such as the presence and absence of pictorial support and the use of a single picture versus a sequence of pictures during discourse production. These tasks can be used to assess executive function, a group of cognitive skills that is integral to the planning of episodes in a narrative and the ordering of events in a story based on a sequence of pictures. Discourse production tasks can also be used to assess theory of mind skills. A narrator must decide what information a hearer knows and can be left implicit in a narrative, and what information must be explicitly stated. These judgements involve mentalizing or theory of mind. Also, the actions of characters in a narrative are motivated by mental states, the articulation of which explains *why* these characters behave as they do. Attributing mental states to characters in a narrative also requires the use of the narrator's theory of mind skills.

Discourse production tasks are also a more ecologically valid way in which to assess cognitive abilities such as memory and attention. Demands on memory and attention during narration, for example, are altogether different from those that are tested in the memory and attention domains of cognitive assessments such as the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) – tasks in these MoCA domains require examinees to recall of a list of words (memory) and to repeat a list of digits in forward and backward order (attention). It is not difficult to see how an adult with Long COVID might pass these MoCA tasks and yet have memory and attention problems that compromise language use in a range of everyday communicative contexts. In fact, it is often reported by adults with Long COVID that they passed cognitive screening using assessments such as MoCA but that they nevertheless experience significant cognitive difficulties when using spoken and written language to communicate. One 65-year-old woman with Long COVID remarked of her cognitive assessment as follows:

Woman with Long COVID (39 months post onset):

> "I can pass your tests in a quiet room but in my life I can barely function. At least not reliably. The world is not a controlled environment and applying cognition isn't the same as your tests. I begged for them to explore functional data instead of just tests and I said that as a clinical psychologist who had experience with them."

In Section 4, it was described how cognitive-linguistic difficulties in Long COVID are a type of cognitive-communication disorder, akin to the cognitive-communication disorders that speech-language pathologists are more accustomed to assessing and treating in clients with traumatic brain injury (TBI), right-hemisphere damage (RHD) and neurodegenerative disorders. It is no coincidence that speech-language pathologists also use discourse production tasks to examine cognitive-communication problems in these clinical populations (Steel et al., 2023). Discourse processes such as information management are uniquely sensitive to cognitive disruption in conditions like traumatic brain injury. This explains the observation that adults with TBI often engage in repetitive language (Body and Parker, 2005) – repetitive language, by definition, conveys no new information. Adults with TBI also omit information and present information in an incorrect order (Pistono et al., 2019; Power et al., 2020). These difficulties with the management of information in discourse are also apparent in the language of adults with RHD and neurodegenerative disorders (Berube et al., 2022). That it is now proposed that language difficulties in adults with Long COVID should be assessed using the same discourse production tasks that are used to assess communication problems in people with TBI, RHD and neurodegenerative disorders is further confirmation of the diagnostic status of COVID-related language problems as a type of cognitive-communication disorder.

Adults with Long COVID also present an intervention challenge for speech-language pathologists. This population of clients is significantly younger than most adults who are assessed and treated by speech-language pathologists – the adults with Long COVID in this follow-up study were 48.8 years on average, while clients with aphasia and neurodegenerative disorders are generally in their sixth, seventh and eighth decades of life. This age difference is important as it means that issues such as employment must be given prominence in the rehabilitation of clients with Long COVID – a return to employment may be less pressing for older clients with aphasia and neurodegenerative disorders. Although there is still no evidence base for communication interventions for people with Long COVID, there are some guiding principles that can be applied to the treatment of this population of clients. These principles are set out below. For further discussion of intervention in people with Long COVID and cognitive-communication disorders, readers are referred to the clinical guidelines of the Royal College of Speech and Language Therapists (2023).

(1) *Focus on discourse-level interventions* – This follow-up study has clearly shown that it is high-level discourse skills that are most disrupted by cognitive dysfunction in Long COVID. These are the skills that allow us to plan utterances to accommodate the information needs of hearers, to relate events through causal and temporal relations, and to draw inferences that facilitate language comprehension. Word- and sentence-level interventions of the kind used to treat people with aphasia are unlikely to prove effective in the rehabilitation of adults with Long COVID and may serve only to exacerbate the fatigue in the condition. (Of course, it should be acknowledged that adults with Long COVID can also have aphasia, especially following severe COVID-19 disease.) Discourse skills can be addressed both through conversation, a form of dialogical discourse, and monological discourse such as storytelling activities. (In reality, of course, these forms of discourse often merge such as when we tell stories during conversation.) Discourse-level interventions permit speech-language pathologists to target the interface between language and cognitive processes such as executive functions, an area of documented compromise in the post COVID-19 condition.

(2) *Focus on communication in naturalistic settings* – Interventions for Long COVID should target conversation skills in naturalistic contexts. The cognitive challenges of these contexts can be overwhelming for people with Long COVID. But they can be controlled so that adults with Long COVID can build their way back into communication without triggering a significant relapse in their condition. This "graded communication approach" helps people with Long COVID regain their language and communication skills in an incremental fashion alongside recovery of cognitive functions such as attention and memory (see Fig. 4). The focus on naturalistic settings has implications for how speech-language pathology is delivered to adults with Long COVID. Interventions delivered in clinics do not replicate the cognitive demands of the workplace or the social environments that adults with Long COVID successfully navigated prior to their COVID illness. But they can provide a useful starting point for the early practice and consolidation of communication skills. A graded communication approach can then take these skills and develop them within interactions of greater cognitive complexity such as interactions that involve several participants or that have background distractions that compete for a speaker's attention.

(3) *Focus on continual monitoring and modification* – The only thing that can be said with any certainty about Long COVID is that it is an unpredictable condition. Within even a few hours, adults have reported significant changes in their symptoms, including the ability to communicate. This unpredictable course makes the management of the condition by the individual with Long COVID and by health professionals particularly challenging. The fluctuating course of Long COVID means that when a rehabilitation program is established, it must be continually monitored and modified to meet the changing needs of the person with Long COVID. Communication activities and goals must be revised as clients experience changes in their condition. This may involve the cessation of treatment to allow a patient to recover their baseline level of functioning following a severe relapse or a return to an earlier stage of intervention when cognitive symptoms are acute. In all cases, symptom stabilization cannot be assumed and gains in therapy cannot be regarded as permanent. The intervention model is one of continual revision at the level of tasks, activities, and goals, with clinicians rapidly adapting to new challenges created by fatigue and other Long COVID symptoms.

(4) *Advocacy for adults with Long COVID* – Finally, speech-language pathologists have always viewed it as part of their professional role to undertake advocacy for clients in their care with policy makers, healthcare providers, and employers. This advocacy role is particularly important for clinicians who are working with clients who have Long COVID. This follow-up study has demonstrated clearly that communication difficulties in Long COVID prevent a return to work. Moreover, adults with Long COVID often receive few, if any, adjustments from employers and are required to comply with phased returns that are

Managing communication difficulties in Long Covid

1 March 2023

Researcher
Prof. Louise Cummings

Enquiry Contact
louise.cummings@polyu.edu.hk

Who should read this?

If you have Long Covid and have problems communicating with others, then this leaflet is for you. These problems might occur during speech and writing, or when you are trying to understand what others are saying in conversation. Communication problems may negatively affect your interactions with colleagues at work or your relationships with friends and family. You may react by trying to avoid interactions that you know will cause you distress or embarrassment, or you may depend on others to communicate on your behalf. This leaflet will give you some simple tips to help you deal with Covid-related communication difficulties.

How is communication compromised by Long Covid?

Speech

You may find yourself slurring certain words and your speech may be unintelligible to others. This may be more pronounced at certain times of the day or after exertion. Your speech may be less clear when you are fatigued. You may also find that your speech is less fluent that it was before you developed Covid-19 and that you repeat sounds, syllables, and words.

Language

You may have word-finding difficulties and need to use gestures in place of the word you want to say. You may swap the positions of words in sentences and utterances. You may start to say something and have to abandon it in the middle of an utterance. You might find it difficult to understand what others are saying, especially if they speak rapidly.

Voice

Your voice may sound weak, breathy, or hoarse. This may persist long after your acute Covid infection when you experienced considerable coughing. Your voice may not be adequate to the demands of your job, and you may try to compensate by increasing your volume and straining your voice.

Hearing

You might have some hearing loss following your Covid infection. This may be most evident when there is background noise that you cannot control or when you are not directly facing the person you are talking to. You may also experience tinnitus for the first time. The buzzing and ringing sounds that are typical of tinnitus may be severe enough to prevent you sleeping at night, leading to further fatigue and distress.

How common are communication problems in Long Covid?

In a study of 92 adults with Covid-19, 81 of whom had Long Covid, symptoms were recorded at *Covid onset* and at *any stage* of Covid illness (Cummings, 2023). The following chart displays the percentage of individuals with communication, swallowing, and cognitive problems at any stage of their Covid illness.

COMMUNICATION, SWALLOWING, and COGNITIVE PROBLEMS IN ADULTS WITH COVID-19

Cognitive issues	54.4%
Speech and language problems	25.0%
Tinnitus	13.0%
Laryngitis and voice problems	5.4%
Hearing loss	3.3%
Swallowing problem	2.2%

Who assesses and treats communication difficulties?

The health professionals who assess and treat communication difficulties are **speech and language therapists** for the most part. In the UK, you can refer yourself to speech and language therapy (SLT) by contacting the SLT team at your local hospital (it is an open referral system). Alternatively, a doctor or other medical professional can refer you to SLT. The professional bodies that represent SLTs are the Royal College of Speech and Language Therapists (RCSLT) in the UK and the American Speech-Language-Hearing Association (ASHA) in the US. Both bodies have online resources relating to Covid-19 that you can access here: RCSLT ASHA

Other professionals are also involved in the assessment and treatment of Covid-related communication difficulties. If you have a voice problem or have experienced hearing loss or tinnitus since developing Covid-19, you may need to be assessed by an **Ear, Nose and Throat (ENT) specialist** or an **otolaryngologist**. These medical professionals can examine your larynx or voice box and check if there is an organic cause of your vocal difficulties. They can also examine the structure and function of the organs in your ear that permit you to hear and achieve balance. They may decide that your hearing should be more fully assessed by undergoing audiometric testing by an **audiologist**.

Finally, because so many communication difficulties in Long Covid are related to underlying cognitive problems, you may need to be assessed by a **neuropsychologist**. These professionals assess all aspects of cognition, including attention, memory, processing speed, and reasoning.

Simple tips to improve communication in Long Covid

Everyone with Long Covid experiences debilitating fatigue. This is not like normal fatigue from which we rebound after a night's sleep or a short period of rest. Covid-related fatigue both contributes to communication difficulties in people with Long Covid and can be exacerbated by efforts to communicate. These simple tips will help you manage your problems with communication:

1. **Start** to think of communication as an activity that requires *cognitive effort* in exactly the same way that walking or running requires *physical effort*. Cognitive effort is not a limitless resource even when you did not have Long Covid – we all have a maximum amount of information that we can store in memory, a maximum speed at which we can formulate an utterance, and so on. Now think of this maximum level as having decreased as a result of Long Covid. This is the new level of cognitive resource that you have available for daily activities, including communication.

2. **Good** cognitive health depends on good physical health. As your physical symptoms improve, you can expect to see an improvement in your cognitive status, including your ability to communicate. When you are having a relapse and your physical symptoms are severe, practice strict physical and cognitive pacing. Shut down all cognitive stimulation in an effort to rest. You are not resting if you are reading a book, listening to music, or watching the TV while you are lying on a sofa. Your brain is having to undertake considerable cognitive work during each of these activities.

3. **When** your physical symptoms lessen and you want to interact with others, take a graded approach to communication. Start by arranging to meet a trusted person who is aware of your condition and its impact on your ability to communicate.

4. **Meet** this person in a quiet environment like your home rather than a busy coffee shop or restaurant. Tell this individual how long you will be able to communicate with them. Bring the interaction to an end even if you feel like you would like to extend it. It is better to have a short interaction initially which can be repeated for a slightly longer period of time than to have an extended interaction which triggers a significant crash for several days.

5. **Do** not be afraid to tell your trusted person that you want them to slow down their speaking rate to help you process what they are saying. You may also want to tell them to decrease or increase their speaking volume depending on your needs or even sit quietly with you for a few minutes if you feel overloaded by the interaction. They will understand your difficulties and will be prepared to make these simple adjustments to help you.

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Department of English and Communication 英文及傳意學系

Fig. 4. Guidelines for managing cognitive-linguistic difficulties in adults Long COVID.

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6 **When** you feel you can communicate adequately with this person over a particular period of time without triggering a deterioration in your symptoms, you can begin to increase the cognitive demands of the interaction. Make **one** adjustment at a time. This may be to increase the length of time you meet your trusted partner **OR** to meet your trusted partner for the same length of time as before but in an environment that has some background noise. Do not attempt to increase the length of time that you meet for **AND** to have your meeting in a noisier environment – this will likely overload you.

7 **When** you are able to meet your trusted partner over several occasions and with steadily increasing cognitive demands (e.g. more time, more background distraction), you will want to think about introducing a third person into your interactions. Again, this should be someone who is aware of your difficulties and of the need to adjust their communication style to your current needs.

8 **Meet** this third person for a short period of time initially and with other cognitive demands kept to a minimum. If this three-person interaction is overwhelming, then return to an earlier stage in your graded communication approach. Work on achieving a more consistent level of communication at this earlier stage before attempting to scale up to a more demanding three-person interaction.

9 **When** interacting with two other people, establish some ground rules with them to avoid you becoming overloaded in the interaction. Ask both parties to speak more slowly than they might otherwise do. Also encourage them to avoid overlapping talk which will be difficult for you to process – one person speaks at a time. Be clear in advance about the duration of an interaction and any sensory sensitivities you may have to ambient noise and lighting.

10 **All** of the above points relate to spoken communication during in-person interaction. But you will also need to make adjustments to other forms of communication. Rather than make phone calls which leave you fatigued, ask family members and friends to communicate with you by texts or email. Written communication gives you more time to process and edit what you want to say. Texts and emails are also a written record of information that you can read multiple times to aid comprehension and to refresh your memory. Use the accessibility settings on your mobile phone to help you write texts and understand the texts you receive from others.

Voice problems in Long Covid

Voice problems are also common in people with Long Covid. During the acute stage of your Covid infection, you may have coughed repeatedly to help clear mucus from your lungs. However, cough can become persistent in Long Covid and is related to laryngeal hypersensitivity and dysfunction (Kang et al., 2022). While you are waiting to have your vocal difficulties assessed by an ENT specialist and speech and language therapist, there are several things that you can do to maintain good vocal hygiene and reduce the strain on your voice:

1 Keep yourself well hydrated, and not just in warm weather. The tissues of the larynx (voice box) will lose moisture if you are dehydrated, and they will not vibrate normally as a result. They will also be more susceptible to damage from irritants like smoke.

2 Avoid or limit your intake of caffeinated drinks and alcohol, both of which can dry out the tissues of the larynx.

3 Some prescription medications (e.g., diuretics) can also cause laryngeal tissues to become dehydrated. These medications are treating other important medical problems, so you should not discontinue them. But you should tell your ENT specialist and speech and language therapist about the medications that you are taking.

4 Use a humidifier at home. Thirty percent humidity is recommended. Also, be aware of the drying effects that the use of car radiators can have on the larynx.

5 Avoid irritants such as tobacco smoke. Stop smoking and do not inhale the second-hand smoke of other people.

6 If you experience heartburn or GERD (gastroesophageal reflux disease) after eating spicy foods, use medications to treat it effectively. Persistent, untreated GERD can damage the tissues of the larynx.

7 Take vocal rest during the day. This is especially important if you are placing heavy occupational demands on your voice. Vocal rest conserves your energy – especially important in Long COVID – and gives the tissues of your larynx time to recover from excessive use.

8 Think about workplace adjustments that can help you avoid straining your voice. If you teach or speak in public, use a microphone. Try to avoid talking over background noise as it will cause you to increase your vocal volume. Sit quietly during breaks at work to give your voice time to recover.

For more guidance on voice, visit the National Institute on Deafness and Other Communication Disorders.

Finally……

The advice in this leaflet assumes that you are also practicing excellent physical and mental self-care. So, **eat well, get plenty of rest, and avoid situations that cause you stress!**

Additional resources

Cummings, L. (ed.) (2023) *COVID-19 and Speech-Language Pathology*. New York: Routledge (Chapter 5; Chapter 6)

Long Covid Nurses & Midwives UK (LCNMUK).

Royal College of Speech and Language Therapists (2023) Long Covid: What is it and how can speech and language therapists support people living with it? (RCSLT)

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Department of English and Communication 英文及傳意學系

Fig. 4. (*continued*).

poorly suited to their needs. Speech-language pathologists can, and should, act as advocates on behalf of their clients, particularly with employers. They are the health professionals who are best placed to advise employers on the adjustments that can facilitate a return to work in adults with communication difficulties in Long COVID. For some adults, this may involve a temporary change of role that does not involve interactions with patients or the public that place high demands on communication skills. Simple reassignment of duties such as not answering work telephone calls can also facilitate adults with Long COVID in returning to the workplace. By informing employers of tailored adjustments that they can implement and reminding them of their legal duties to undertake these adjustments, speech-language pathologists can be a powerful facilitator of work re-integration for adults with Long COVID.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

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Appendix

Box 1
Pairwise comparisons between groups.

	Group i	Group j	M_{diff} (i-j)	SE	P
Test 1	FirstCovid	FirstHealthy	-2.20	0.52	< 0.001
Immediate	FirstCovid	SecCovid	0.20	0.44	1.000
Recall	FirstCovid	SecHealthy	-1.85	0.52	0.003
	FirstHealthy	SecCovid	2.40	0.53	< 0.001
	FirstHealthy	SecHealthy	0.35	0.55	1.000
	SecCovid	SecHealthy	-2.05	0.52	0.001
Test 2	FirstCovid	FirstHealthy	-.644	0.36	.468
Picture	FirstCovid	SecCovid	-2.57	0.31	< 0.001
Description	FirstCovid	SecHealthy	-2.90	0.36	< 0.001
	FirstHealthy	SecCovid	-1.93	0.36	< 0.001
	FirstHealthy	SecHealthy	-2.26	0.38	< 0.001
	SecCovid	SecHealthy	-0.33	0.36	1.000
Test 3	FirstCovid	FirstHealthy	-0.24	0.24	1.000
Sentence	FirstCovid	SecCovid	-0.17	0.20	1.000
Generation	FirstCovid	SecHealthy	-0.17	0.23	1.000
	FirstHealthy	SecCovid	0.07	0.24	1.000
	FirstHealthy	SecHealthy	0.07	0.25	1.000
	SecCovid	SecHealthy	-0.004	0.23	1.000
Test 4	FirstCovid	FirstHealthy	-1.54	0.71	0.191
Horseshoe	FirstCovid	SecCovid	0.88	0.59	0.837
Incident	FirstCovid	SecHealthy	0.54	0.70	1.000
	FirstHealthy	SecCovid	2.42	0.71	0.005
	FirstHealthy	SecHealthy	2.08	0.75	0.038
	SecCovid	SecHealthy	-0.34	0.70	1.000
Test 5	FirstCovid	FirstHealthy	-13.44	2.75	< 0.001
Letter	FirstCovid	SecCovid	-1.92	2.27	1.000
Fluency	FirstCovid	SecHealthy	-7.94	2.67	0.021
	FirstHealthy	SecCovid	11.52	2.75	< 0.001
	FirstHealthy	SecHealthy	5.50	2.89	0.358
	SecCovid	SecHealthy	-6.03	2.67	0.154
Test 6	FirstCovid	FirstHealthy	-5.15	1.25	< 0.001
Category	FirstCovid	SecCovid	3.84	1.05	0.002
Fluency:	FirstCovid	SecHealthy	2.49	1.23	0.268
Fruit	FirstHealthy	SecCovid	8.99	1.25	< 0.001
	FirstHealthy	SecHealthy	7.63	1.32	< 0.001

(*continued on next page*)

Box 1 (*continued*)

	Group i	Group j	M_{diff} (i-j)	SE	P
	SecCovid	SecHealthy	-1.35	1.23	1.000
Test 7	FirstCovid	FirstHealthy	-0.27	0.96	1.000
Category	FirstCovid	SecCovid	3.21	0.81	0.001
Fluency:	FirstCovid	SecHealthy	1.42	0.95	0.814
Vehicles	FirstHealthy	SecCovid	3.48	0.96	0.003
	FirstHealthy	SecHealthy	1.69	1.02	0.589
	SecCovid	SecHealthy	-1.79	0.95	0.370
Test 8	FirstCovid	FirstHealthy	-3.55	1.67	0.216
Little Red	FirstCovid	SecCovid	4.03	1.40	0.029
Riding Hood	FirstCovid	SecHealthy	2.67	1.65	0.644
	FirstHealthy	SecCovid	7.58	1.68	< 0.001
	FirstHealthy	SecHealthy	6.22	1.77	0.004
	SecCovid	SecHealthy	-1.36	1.65	1.000
Test 9	FirstCovid	FirstHealthy	-0.40	0.30	1.000
Procedural:	FirstCovid	SecCovid	-0.36	0.25	0.918
Laundry	FirstCovid	SecHealthy	0.09	0.29	1.000
	FirstHealthy	SecCovid	0.04	0.30	1.000
	FirstHealthy	SecHealthy	0.49	0.32	0.733
	SecCovid	SecHealthy	0.45	0.29	0.765
Test 10	FirstCovid	FirstHealthy	-0.28	0.33	1.000
Procedural:	FirstCovid	SecCovid	-0.57	0.27	0.232
Coffee	FirstCovid	SecHealthy	-0.22	0.32	1.000
	FirstHealthy	SecCovid	-0.30	0.33	1.000
	FirstHealthy	SecHealthy	0.05	0.35	1.000
	SecCovid	SecHealthy	0.35	0.32	1.000
Test 11	FirstCovid	FirstHealthy	0.04	0.47	1.000
Confrontation	FirstCovid	SecCovid	-0.70	0.39	0.464
Naming	FirstCovid	SecHealthy	-0.81	0.46	0.486
	FirstHealthy	SecCovid	-0.73	0.47	0.718
	FirstHealthy	SecHealthy	-0.84	0.49	0.539
	SecCovid	SecHealthy	-0.11	0.46	1.000
Test 12	FirstCovid	FirstHealthy	-2.92	0.55	< 0.001
Delayed	FirstCovid	SecCovid	-0.31	0.46	1.000
Recall	FirstCovid	SecHealthy	-2.46	0.54	< 0.001
	FirstHealthy	SecCovid	2.62	0.55	< 0.001
	FirstHealthy	SecHealthy	0.46	0.58	1.000
	SecCovid	SecHealthy	-2.16	0.54	0.001

Note: M_{diff}(i-j) = mean difference between Group i and Group j, SE = standard error, and p = p-value. p-values were adjusted for multiple comparisons using the Bonferroni method.

Box 2
Descriptive statistics of performance in the 12 language task.

	FirstCovid (N = 41)		SecCovid (N = 41)		FirstHealthy (N = 26)		SecHealthy (N = 26)	
	M (SD)	Mdn (IQR)	M (SD)	Mdn (IQR)	M (SD)	Mdn (IQR)	M (SD)	Mdn (IQR)
Test 1	**7.73** (2.17)	7.5 (3.0)	7.51 (1.99)	7.5 (3.3)	9.73 (1.97)	10 (3.1)	**9.42** (1.95)	9.25 (2.1)
Test 2	**7.18** (1.58)	7 (2.0)	9.77 (1.29)	10 (1.5)	7.79 (1.27)	8 (1.5)	**10.10** (1.60)	10.5 (2.1)
Test 3	**5.00** (0.84)	5 (2.0)	5.17 (1.00)	5 (1.0)	**5.23** (0.86)	5 (1.0)	5.19 (0.94)	5.5 (2.0)
Test 4	12.37 (2.91)	13 (3.8)	**11.52** (2.66)	11 (4.8)	**13.85** (2.94)	14 (4.5)	11.81 (2.65)	11.5 (5.0)
Test 5	**35.10** (10.13)	32 (16.0)	37.10 (10.50)	36 (16.0)	**48.08** (10.86)	50 (17.0)	42.85 (10.04)	45 (18.0)
Test 6	20.71 (5.90)	21 (9.0)	**16.85** (3.97)	17 (5.0)	**25.81** (4.73)	25 (7.0)	18.35 (4.54)	18 (6.0)
Test 7	15.10 (4.16)	15 (5.0)	**11.90** (3.03)	11 (3.0)	**15.31** (3.73)	15 (5.0)	13.73 (3.85)	13.5 (7.0)
Test 8	28.76 (6.52)	28 (10.0)	**24.70** (6.63)	23.5 (9.3)	**32.10** (5.77)	31 (7.5)	25.94 (6.06)	25.25 (12.1)

(continued on next page)

Box 2 (*continued*)

	FirstCovid (N = 41)		SecCovid (N = 41)		FirstHealthy (N = 26)		SecHealthy (N = 26)	
Test 9	6.32 (0.96)	7 (1.0)	6.68 (1.06)	7 (2.0)	**6.69** (0.98)	7 (1.3)	**6.23** (1.58)	6 (3.0)
Test 10	**6.24** (1.16)	6 (1.8)	**6.82** (1.07)	7 (2.0)	6.58 (1.42)	7 (2.0)	6.52 (1.36)	7 (2.5)
Test 11	**17.61** (1.90)	18 (2.0)	18.32 (1.80)	19 (2.0)	17.62 (2.08)	18 (2.0)	**18.50** (1.27)	19 (1.0)
Test 12	**6.62** (2.20)	6.5 (2.5)	6.90 (2.15)	6.5 (2.5)	**9.39** (2.08)	9.5 (4.0)	8.96 (2.07)	8.5 (4.0)

Note: N = sample size, M = mean, SD = standard deviation, Mdn = median, and IQR = interquartile range. N = 40 for Test 2 of FirstCovid, N = 25 for Test 5 of FirstHealthy, and N = 25 for Test 10 of SecHealthy. For each test, black bold text indicated the highest score, and red bold text indicated the lowest score among the four groups.

Box 3
GLM results (Type III F-test).

DV	Source	F	df1	df2	P	H	R^2
Test 1	Group	10.510	3	127	< 0.001	0.199	0.241
	Gender	1.673	1	127	0.198	0.013	
	Education	0.015	1	127	0.902	0.0004	
	Age	5.456	1	127	0.021	0.041	
Test 2	Group	36.589	3	126	< 0.001	0.466	0.506
	Gender	0.836	1	126	0.362	0.007	
	Education	6.779	1	126	0.010	0.051	
	Age	10.938	1	126	0.001	0.080	
Test 3	Group	0.431	3	127	0.731	0.010	0.063
	Gender	0.537	1	127	0.465	0.004	
	Education	6.331	1	127	0.013	0.047	
	Age	0.237	1	127	0.627	0.002	
Test 4	Group	4.343	3	127	0.006	0.093	0.169
	Gender	0.202	1	127	0.654	0.002	
	Education	0.476	1	127	0.492	0.004	
	Age	12.835	1	127	< 0.001	0.092	
Test 5	Group	9.203	3	126	< 0.001	0.180	0.216
	Gender	0.780	1	126	0.379	0.006	
	Education	1.544	1	126	0.216	0.012	
	Age	3.359	1	126	0.069	0.026	
Test 6	Group	19.661	3	127	< 0.001	0.317	0.363
	Gender	0.658	1	127	0.419	0.005	
	Education	8.479	1	127	0.004	0.063	
	Age	0.485	1	127	0.487	0.004	
Test 7	Group	6.866	3	127	< 0.001	0.140	0.175
	Gender	0.585	1	127	0.446	0.005	
	Education	5.358	1	127	0.022	0.040	
	Age	0.553	1	127	0.458	0.004	
Test 8	Group	8.118	3	127	< 0.001	0.161	0.173
	Gender	0.231	1	127	0.632	0.002	
	Education	0.056	1	127	0.813	0.0004	
	Age	1.154	1	127	0.285	0.009	
Test 9	Group	1.504	3	127	0.217	0.034	0.063
	Gender	0.455	1	127	0.501	0.004	
	Education	2.771	1	127	0.098	0.021	
	Age	1.404	1	127	0.238	0.011	
Test 10	Group	1.471	3	126	0.226	0.034	0.042
	Gender	0.136	1	126	0.713	0.001	
	Education	0.846	1	126	0.359	0.007	
	Age	0.141	1	126	0.708	0.001	
Test 11	Group	2.038	3	127	0.112	0.046	0.096

(*continued on next page*)

Box 3 (*continued*)

DV	Source	F	df1	df2	P	H	R^2
	Gender	0.079	1	127	0.779	0.001	
	Education	5.908	1	127	0.016	0.044	
	Age	1.402	1	127	0.239	0.011	
Test 12	Group	13.958	3	127	< 0.001	0.248	0.305
	Gender	0.964	1	127	0.328	0.008	
	Education	0.002	1	127	0.963	0.00002	
	Age	8.782	1	127	0.004	0.065	

Note: F = F-statistic, df1 = degrees of freedom of the numerator, df2 = degrees of freedom of the denominator, p = p-value, η^2 = partial eta squared (representing the effect size), and R^2 = R squared (i.e., the coefficient of determination).

Box 4
Parameter estimate for age.

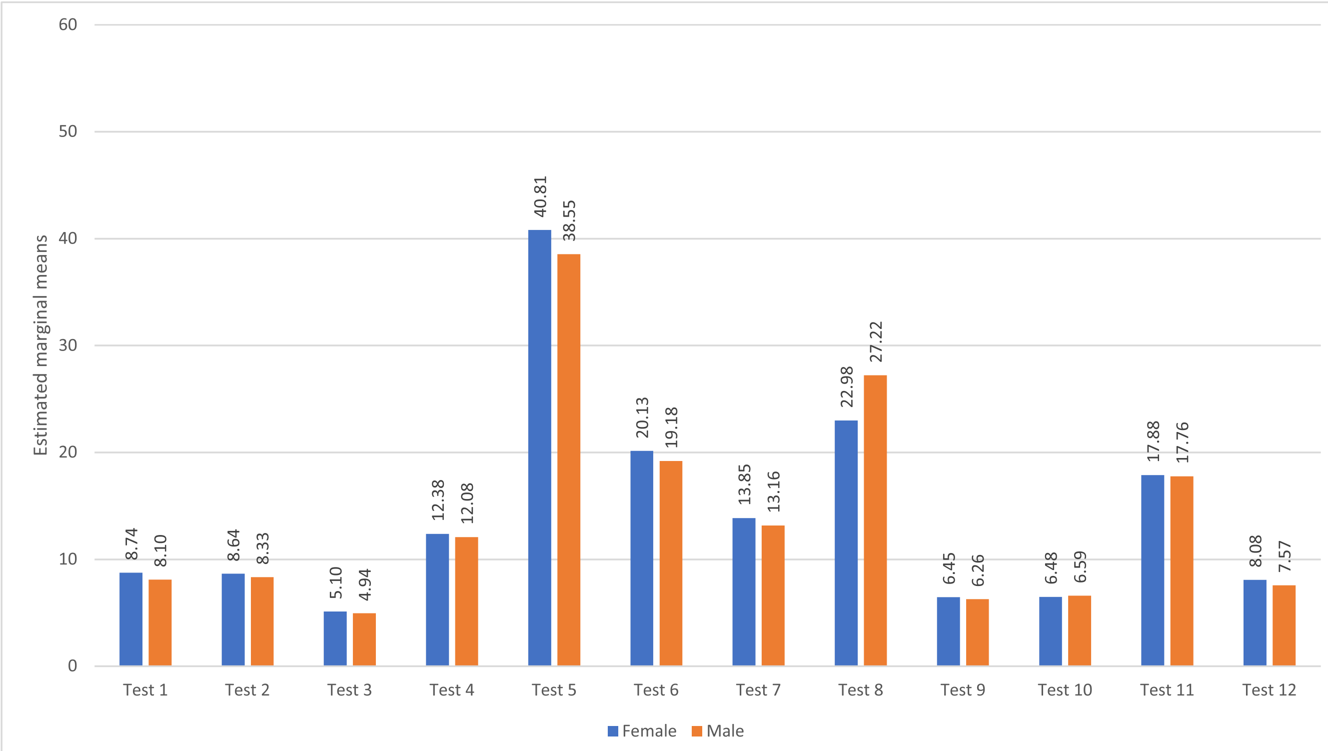
	β	SE	95% CI	t	df	p
Test 1	-0.003	0.001	[− 0.006, − 0.001]	-2.336	127	0.021
Test 2	0.003	0.001	[0.001, 0.005]	3.307	126	0.001
Test 3	0.0003	0.001	[− 0.001, 0.002]	0.487	127	0.627
Test 4	0.007	0.002	[0.003, 0.011]	3.583	127	< 0.001
Test 5	0.014	0.007	[− 0.001, 0.028]	1.833	126	0.069
Test 6	-0.002	0.003	[− 0.009, 0.004]	-0.697	127	0.487
Test 7	0.002	0.003	[− 0.003, 0.007]	0.744	127	0.458
Test 8	-0.005	0.005	[− 0.014, 0.004]	-1.074	127	0.285
Test 9	0.001	0.001	[− 0.001, 0.003]	1.185	127	0.238
Test 10	0.0003	0.001	[− 0.001, 0.002]	0.375	126	0.708
Test 11	0.002	0.001	[− 0.001, 0.004]	1.184	127	0.239
Test 12	-0.004	0.001	[− 0.007, − 0.001]	-2.964	127	0.004

Note: β = parameter estimate, SE = standard error, CI = confidence interval, t = t-statistic,df = degrees of freedom, and p = p-value.

Box 5
Estimated marginal means (M (SE)) of performance in language tasks (for categorical variables only).

	Group				Gender		Education	
	FirstCovid	SecCovid	FirstHealthy	SecHealthy	Female	Male	Under 17	Over 17
Test 1	7.46 (0.38)	7.26 (0.38)	9.66 (0.40)	9.31 (0.41)	8.74 (0.22)	8.10 (0.43)	8.45 (0.34)	8.40 (0.26)
Test 2	6.96 (0.26)	9.53 (0.26)	7.60 (0.28)	9.86 (0.28)	8.64 (0.15)	8.33 (0.30)	8.15 (0.23)	8.82 (0.18)
Test 3	4.87 (0.17)	5.04 (0.17)	5.11 (0.18)	5.05 (0.19)	5.10 (0.10)	4.94 (0.19)	4.81 (0.15)	5.23 (0.12)
Test 4	12.21 (0.51)	11.32 (0.51)	13.74 (0.55)	11.67 (0.56)	12.38 (0.30)	12.08 (0.58)	12.06 (0.46)	12.41 (0.35)
Test 5	33.85 (1.95)	35.77 (1.95)	47.29 (2.12)	41.79 (2.13)	40.81 (1.14)	38.55 (2.22)	38.47 (1.74)	40.88 (1.35)
Test 6	19.95 (0.90)	16.11 (0.90)	25.09 (0.96)	17.46 (0.98)	20.13 (0.52)	19.18 (1.02)	18.35 (0.80)	20.95 (0.62)
Test 7	14.59 (0.69)	11.39 (0.69)	14.86 (0.74)	13.17 (0.76)	13.85 (0.40)	13.16 (0.79)	12.71 (0.62)	14.30 (0.48)
Test 8	28.38 (1.20)	24.35 (1.21)	31.93 (1.29)	25.71 (1.32)	22.98 (0.70)	27.22 (1.37)	27.45 (1.08)	27.74 (0.83)
Test 9	6.19 (0.21)	6.55 (0.22)	6.59 (0.23)	6.10 (0.24)	6.45 (0.13)	6.26 (0.24)	6.18 (0.19)	6.54 (0.15)
Test 10	6.27 (0.24)	6.84 (0.24)	6.54 (0.25)	6.49 (0.26)	6.48 (0.14)	6.59 (0.27)	6.43 (0.21)	6.64 (0.17)
Test 11	17.45 (0.34)	18.15 (0.34)	17.42 (0.36)	18.26 (0.37)	17.88 (0.20)	17.76 (0.38)	17.41 (0.30)	18.23 (0.23)
Test 12	6.40 (0.39)	6.71 (0.39)	9.32 (0.42)	8.86 (0.43)	8.08 (0.23)	7.57 (0.45)	7.83 (0.35)	7.82 (0.27)

Note: M = mean and SE = standard error.



Box 6. Estimated marginal means of performance in language tasks by gender.

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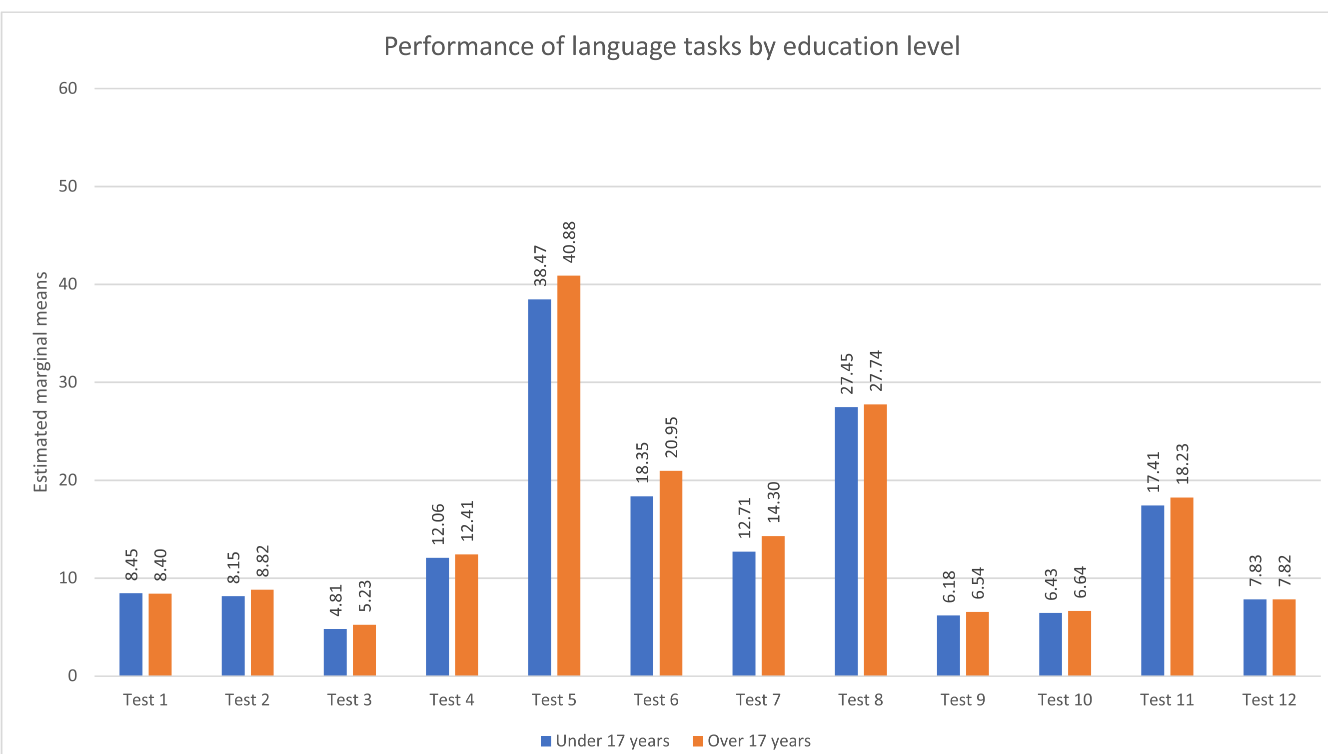
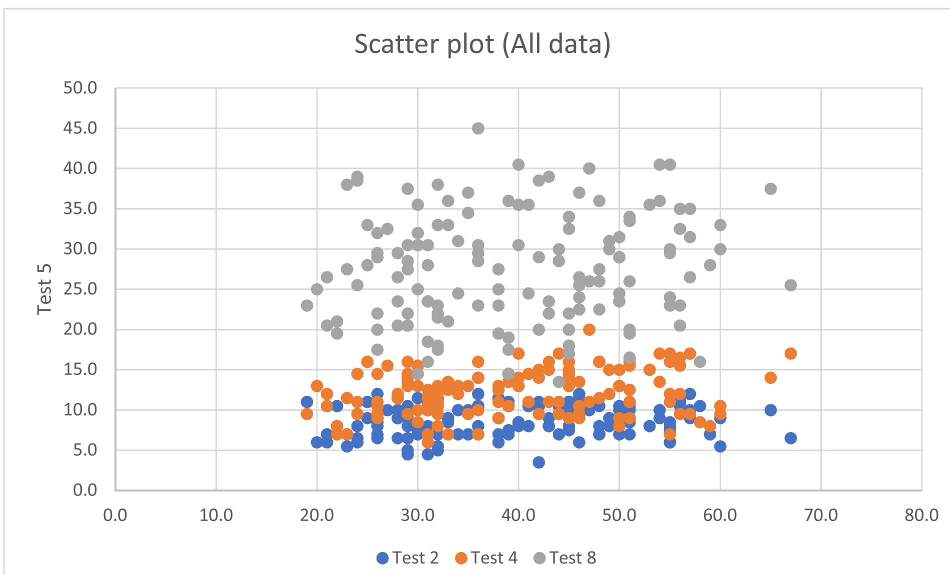


Box 7. Estimated marginal means of performance in language tasks by education level.

Box 8
Pearson's correlation coefficients (r (p)).

	Test 5 vs. Test 2	Test 5 vs. Test 4	Test 5 vs. Test 8
All data	0.180 (0.039)	0.243 (0.005)	0.114 (0.191)
By group			
FirstCovid	0.247 (0.124)	0.340 (0.029)	0.017 (0.917)
SecCovid	0.408 (0.008)	0.321 (0.040)	0.102 (0.528)
FirstHealthy	0.220 (0.291)	0.106 (0.615)	-0.052 (0.805)
SecHealthy	-0.069 (0.739)	-0.247 (0.223)	0.015 (0.941)

Note: r = Pearson's correlation coefficient and p = p-value.



Box 9. Scatter plot of Test 5 against Test 2, Test 4, and Test 8 (All data).

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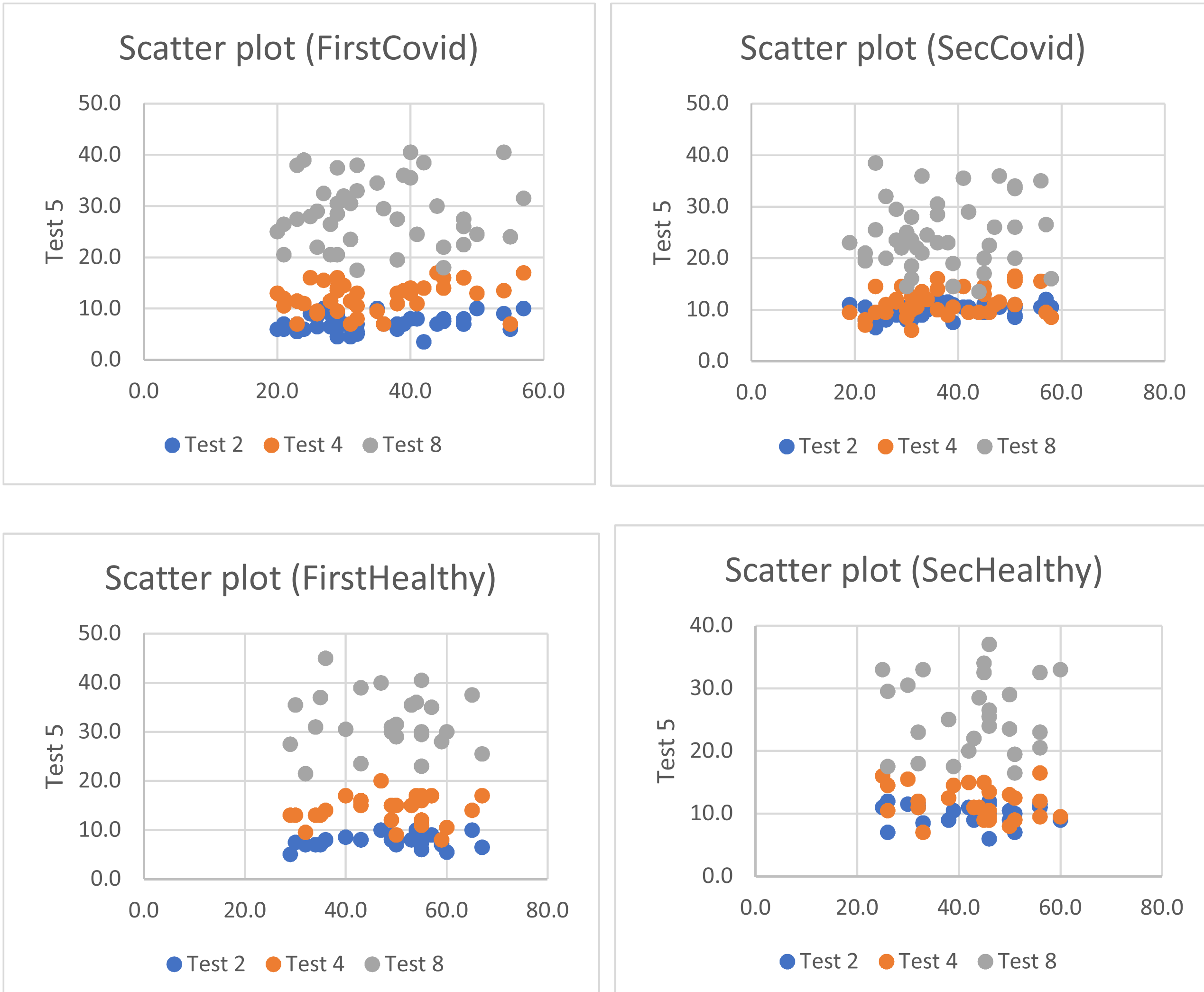

Box 10. Scatter plot of Test 5 against Test 2, Test 4, and Test 8, by group.

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