COVID-19 AND SPEECH-LANGUAGE PATHOLOGY

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First published 2023

ISBN: 978-1-03219-0-075 (hbk)
ISBN: 978-1-03219-0-068 (pbk)
ISBN: 978-1-00325-7-318 (ebk)

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COGNITIVE-LINGUISTIC DIFFICULTIES IN ADULTS WITH LONG COVID

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DOI: 10.4324/9781003257318-5

Routledge
Taylor & Francis Group
NEW YORK AND LONDON

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Louise Cummings

5.1 Introduction

At the time of writing, the health and economic consequences of the COVID-19 pandemic are continuing to unfold. However, it is becoming increasingly clear that the true legacy of this crisis in global health may be the very large number of people who do not make a good recovery from COVID-19 infection. The prevalence of so-called Long COVID is beginning to be quantified. The Office of National Statistics (2022) stated that an estimated 2 million people living in private households in the UK (3.1% of the population) reported experiencing Long COVID as of 1 May 2022. Many of these individuals are adults of working age who are no longer able to work or have had to reduce their working hours because of debilitating physical and mental symptoms. The rehabilitation of these individuals will not only be costly in economic terms but will also require a significant evidence base to support medical interventions and therapies. Work on developing this evidence base is already underway. An area that has so far not received much attention is language and cognition. It will be argued in this chapter that subjective reports of cognitive-linguistic difficulties as part of the Long COVID syndrome are supported by findings from an experimental study of adults with Long COVID. Amongst other things, these adults present with a marked reduction in the informativeness of their spoken discourse that is related to the cognitive demands of different discourse production tasks. The implications of these findings for the role of speech-language pathology in the rehabilitation of these individuals are discussed.

5.2 Long COVID: some background

The COVID-19 pandemic has demonstrated the devastating consequences that a novel virus can have on susceptible human populations around the world.

DOI: 10.4324/9781003257318-5

By 12 March 2022, the World Health Organization reported 6,029,852 deaths from SARS-CoV-2, the novel coronavirus that causes COVID-19 disease. Whilst mortality rates vary with different countries and regions, there is widespread consensus that SARS-CoV-2 has a case fatality rate (mortality in individuals with the disease) of 1% compared to 9.7% in severe acute respiratory syndrome (SARS) and 34% in Middle East respiratory syndrome (MERS) (Petersen et al. 2020). Even in those who survive infection with the SARS-CoV-2 virus, there is a considerable burden of illness, often lasting many months. In a study of 143 Italian patients discharged from COVID-19 hospitalisation, only 18 patients (12.6%) were completely free of any COVID-19 symptoms when assessed a mean of 60.3 days after onset of the first symptom. A further 32% of patients had one or two symptoms, and 55% had three or more symptoms (Carfi et al. 2020). The term "Long COVID" has been coined by people with persistent COVID symptoms to describe the lingering illness that they are experiencing. The World Health Organization (2021) has developed a clinical case definition of what it calls "post COVID-19 condition":

> 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.

This definition recognises that alongside physical symptoms such as fatigue and breathlessness, adults with Long COVID also frequently report an array of cognitive-linguistic difficulties described as "brain fog." This expression captures problems with memory, a lack of attention and concentration, word-finding difficulty in conversation, and struggles with reading and writing. In my work with adults who have Long COVID, many participants have described in detail the nature of these cognitive-linguistic disturbances and the impact of these problems on work and other daily activities. It will be noted from the following testimonies of some of these adults that these symptoms extend well beyond the 12-week period described previously by the World Health Organization:

> *31-year-old woman; 8 months post-onset (reading):*
>
> My reading was impacted severely around July–August 2020. I simply couldn't read one page. My head was spinning, I did not understand what I was reading. At the moment it's still hard to read and understand everything 100%. It takes me much more time than before. Prior to COVID

I would spend hours reading (at work + minimum 1h for my pleasure at home). This is impacted now. I also find it hard to follow scientific articles or books.

33-year-old woman; 6 months post-onset (topic of conversation):

I often forget what the question was midway through answering and if we tangent during the conversation I will have no idea where we started.

61-year-old man; 7 months post-onset (memory):

Seems to be worse. I write more lists. Often struggle to find words and names. When I get into a good phase I find things and projects I've "dropped" and/or forgotten about. I started filling this in a week or so ago, and have just remembered I didn't finish it.

52-year-old woman; 10 months post-onset (language comprehension):

Sometimes I feel like I didn't hear it right, and I don't have hearing issues. I think I'm really not understanding what I'm hearing.

31-year-old woman; 8 months post-onset (word-finding difficulty):

I lose track of my thought process and struggle to find the right word, or I use the wrong one without realising.

53-year-old woman; 10 months post-onset (attention and concentration):

I notice I often "zone out" and miss what is being said. I sometimes struggle to pay attention for long periods.

60-year-old woman; 5 months post-onset (language problems):

Family and friends understand my word blindness, word substitution and losing my way during a sentence etc. It can be highly embarrassing with strangers or those who don't know me well especially with medical matters so I minimise those.

That cognitive-linguistic difficulties should be reported as part of the Long COVID syndrome is not entirely unexpected. It was apparent to Chinese doctors who treated early cases of COVID-19 infection in Wuhan that the SARS-CoV-2 virus affects many organs and systems in the body other than the lungs and respiration (Li et al. 2020). This includes the nervous system. Neurological symptoms (e.g., headache) and complications (e.g., cerebral hemorrhage) are recognised clinical features of patients with COVID-19 infection (Collantes et al. 2021). Also, the SARS-CoV-2 virus has been detected in neural tissue on postmortem examination (Paniz-Mondolfi et al. 2020), although central nervous system (CNS) involvement caused by direct neuroinvasion is believed to be rare relative to CNS sequelae related to systemic hyper-inflammation (Najjar et al. 2020). Neurological findings from seriously ill and deceased patients with COVID-19 infection may not relate directly to non-hospitalised adults with moderate COVID illness. But they do provide a tentative basis for investigating if cognitive-linguistic difficulties in Long COVID might have a neurological basis or are a consequence of factors like fatigue in the Long COVID syndrome.

5.3 An experimental study

In October 2020, I was motivated by increasing media reports and personal accounts of cognitive-linguistic issues in Long COVID to start collecting data from adults who were not making a good recovery from their COVID infections. I contacted several people who were active on online Long COVID support groups in the UK. It was clear to me that reports of brain fog by users of these groups were too numerous and consistent for these difficulties to be a rare feature of Long COVID and that some investigation of these difficulties was warranted. On 15 October 2020, I conducted my first online interview of an adult with Long COVID. The participant was a 61-year-old genetic pathologist who contracted SARS-CoV-2 in March 2020 at the beginning of the first wave of the COVID pandemic in the UK. He was still experiencing significant symptoms some seven months after his acute illness. That case is published elsewhere (Cummings 2021a). It prompted me to embark on an experimental study to establish if there were identifiable cognitive-linguistic deficits in these adults and if such impairments that did exist were neurological consequences of COVID-19 infection or were related to the debilitating fatigue that is reported by people with Long COVID.

Method

Participants

Recruitment to the study was conducted by means of posts on Long COVID and myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) support groups

on Facebook and other forms of social media. The participants were adults who resided in the UK, Ireland, Canada, USA, Australia, Brazil, and Belgium. They emailed me directly after reading posts about the study. All healthy (non-COVID) participants were recruited from amongst academic colleagues, former students, and personal contacts in Hong Kong, mainland China, Belgium, Ireland, and the UK. Each participant signed a consent form and received an information sheet about the study. COVID participants were asked to complete a 38-item questionnaire about their lifestyle and general health prior to COVID infection and the onset and development of their COVID illness. A similar questionnaire was completed by ME/CFS participants. The study was approved by the Human Subjects Ethics Sub-Committee of The Hong Kong Polytechnic University.

Subjects were recruited to one of six groups in the study (see Table 5.1 in Appendix). Adults with Long COVID who reported cognitive-linguistic difficulties ("brain fog") were assigned to a COVID experimental group. Adults with COVID who did not report cognitive-linguistic difficulties were assigned to a COVID control group. Because several COVID participants spoke English as a second language, it was necessary to form a separate group of these subjects and to have a control group of L2 English speakers without COVID. There was also a control group of healthy participants who had not had COVID. A further control group of participants with ME/CFS was included in the study.

The chief reason COVID and ME/CFS control groups were used in the study was that the debilitating fatigue that is a feature of Long COVID is a potential performance limitation on language and cognition. Fatigue adversely impacts cognitive-linguistic performance in healthy individuals and in individuals with conditions like ME/CFS. It is noteworthy that language and cognitive problems are also documented in adults with ME/CFS (Moss 1995; Daly et al. 2001; Park et al. 2001). In the absence of COVID and ME/CFS control participants, the reduced performance of COVID experimental participants on the tasks in the study may simply reflect the fatigue of these participants rather than any COVID-related neurological dysfunction.

With one exception, COVID participants in the study remained at home during their illness. Most received medical advice by telephone, and several had the assistance of paramedics for breathing difficulties and other symptoms (see Figures 5.1 and 5.2 in Appendix for symptoms at onset and overall symptoms, respectively). A few COVID participants attended accident and emergency departments at their local hospitals or had short one- or two-day admissions to hospital for treatment of symptoms. The lack of extended periods of hospitalisation was more a sign of the parlous condition of many medical facilities and health systems at the start of the pandemic than an indication that the symptoms of participants were mild in nature and did not require intensive medical support. The age, gender, and educational background of all participants in the study are displayed in Table 5.1. The occupational status and pre-COVID lifestyles of the 92 COVID participants in the study are displayed in Table 5.2. None of the

participants had a pre-existing language disorder or any condition (e.g., traumatic brain injury) that would place them at risk of such a disorder.

Amongst the 92 adults with COVID in the study, 52 received a clinical diagnosis of COVID infection by a physician, 16 had a positive PCR test, 20 had a positive antibody test, and 4 had a positive PCR *and* antibody test (see Table 5.3 in Appendix).

Interviews

All interviews were conducted online because of COVID restrictions and the geographical distance between the author and participants. Skype or Zoom was used in accordance with the preference of participants. Each participant was interviewed on a date and at a time of their choice. Interviews lasted approximately one hour. One participant became upset at her performance on the tasks and was interviewed in two sessions conducted over consecutive days. All other participants were fully tested in a single session. Adults with COVID were interviewed on average 351.7 days (11.7 months) after the onset of their COVID symptoms. The time between symptom onset and interviews ranged from 102 to 572 days (3.4 to 19.1 months). It should be noted that the timing of interviews of all COVID participants exceeded the 12-week period stipulated in the clinical case definition of the post COVID-19 condition adopted by the World Health Organization.

Tasks and materials

A series of 12 tasks was conducted during each interview. All tasks were administered by the author, who used a standard set of prompts and presented tasks in the same order. Test sessions were recorded using two digital voice recorders (Sony ICD-UX560F) and the record function on either Skype or Zoom. The tasks had previously been used in a study of language in adults with neurodegeneration (Cummings 2020) and had been found to be effective in eliciting high-quality data for linguistic analysis. Each task and its associated instructions are shown as follows:

(1) *Immediate recall*: A 100-word story titled "Sam and Fred" 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."
(2) *Cookie Theft picture description*: This is the picture description task from the Boston Diagnostic Aphasia Examination (Goodglass et al. 2001). Participants were asked to describe a black-and-white line drawing of a domestic scene whilst 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."

(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. Don't worry about the order of the words. You can use the words in any order."

(4) *Flowerpot 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."

(5) *Phonemic (letter) fluency:* Participants are asked to generate words beginning with the letters "F," "A," and "S" in 60 seconds. Instruction: "Tell me as many words as possible that begin with the letter 'F.' Do not use names like *Fred* and multiple words with the same stem but different endings like *friend, friends, friendly*. You have 60 seconds. I will start the stopwatch as soon as you give me the first word with 'F.'"

(6) *Semantic (category) fluency 1:* Participants are asked to generate the names of animals in 60 seconds. Instruction: "Tell me as many names of animals as possible. They can be the names of domestic animals, wild animals, or exotic animals. You have 60 seconds. I will start the stopwatch as soon as you give me the first name of an animal."

(7) *Semantic (category) fluency 2:* Participants are asked to generate the names of vegetables in 60 seconds. Instruction: "Tell me as many names of vegetables as possible. They can be the names of vegetables from all over the world. You have 60 seconds. I will start the stopwatch as soon as you give me the first name of a vegetable."

(8) *Cinderella story:* Participants are shown a wordless picture book of the Cinderella 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 Cinderella. 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 Cinderella story."

(9) *Procedural discourse 1:* Participants are asked to describe the steps that someone would go through to make a cheese and ham sandwich. Instruction: "Can you talk me through all the steps or stages needed to make a cheese and ham sandwich?"

(10) *Procedural discourse 2:* Participants are asked to describe the steps that someone would go through to write a letter to someone. Instruction: "Can you talk me through all the steps or stages needed to write a letter to someone?"

(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."

(12) *Delayed recall:* Participants are asked to recall the 100-word story (Sam and Fred story) that was read aloud to them at the 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?"

Results

The number of essential propositions, correct words, and other responses to each of the 12 tasks was counted. Generalised linear models (GLM) with Poisson distribution were then fitted separately, with the count from each task as the outcome variable and COVID status (i.e., +/- COVID) as the (categorical) predictor variable. The more common independent-samples t-test is inappropriate in this case because count data do not meet the assumption of normal distribution.

The mean and standard deviation for all 12 tests across the six groups in the study are displayed in Table 5.4 in the Appendix. The effect of age, gender, and education on test performance was analysed separately using GLM with Poisson distribution with the count from each task as the outcome variable and age, gender, and education as the predictor variables. There were significant positive effects of age (increasing age resulting in better performance) in 5 of 12 tasks: flowerpot-incident narration ($z=2.439$, $p<0.05$); letter fluency ($z=2.750$, $p<0.05$); category fluency for vegetables ($z=2.126$, $p<0.05$); sandwich-making procedural discourse ($z=2.631$, $p<0.05$); and confrontation naming ($z=2.654$, $p<0.05$). Male subjects performed significantly better than female subjects on letter fluency ($z=2.351$, $p<0.05$) but performed significantly worse than female subjects on category fluency for vegetables ($z=-2.085$, $p<0.05$). There was an effect of education on performance in only one test. Participants with under 17 years of education performed significantly worse on Cinderella narration ($z=-3.655$, $p<0.001$) than participants with 17 or more years of education.

The performance of COVID experimental participants in the study was significantly weaker than that of healthy participants, COVID control participants, and ME/CFS participants in several tests (see Tables 5.5–5.7 in Appendix). The most marked reduction in performance was observed relative to healthy participants, with COVID participants achieving significantly lower scores than healthy participants on 7 of 12 tests: immediate recall ($z=-4.18$, $p<0.001$); delayed recall ($z=-6.47$, $p<0.001$); Cookie Theft picture description ($z=-2.03$, $p<0.05$); flowerpot-incident narration ($z=-2.65$, $p<0.05$); Cinderella narration ($z=-5.98$, $p<0.001$); letter fluency ($z=-7.49$, $p<0.001$); and category fluency for animals ($z=-3.69$, $p<0.001$). However, COVID experimental participants also performed significantly less well than COVID control participants with no self-reported cognitive-linguistic difficulties on 4 of 12 tests: immediate recall ($z=-4.09$, $p<0.001$); delayed recall ($z=-5.33$, $p<0.001$); letter fluency ($z=-7.96$,

$p<0.001$); and Cinderella narration ($z=-4.06$, $p<0.001$). COVID experimental participants performed significantly less well than ME/CFS participants, with whom they share debilitating levels of fatigue, on 3 of 12 tasks: immediate recall ($z=-1.97$, $p=0.05$); delayed recall ($z=-3.89$, $p<0.001$); and Cinderella narration ($z=-3.06$, $p<0.001$).

Other between-group comparisons were also revealing. There were only two significant differences between L2 English speakers with COVID and L2 English healthy participants (compared to significant differences on seven tests in native English speakers). L2 English speakers with COVID had significantly poorer performance than L2 English healthy participants on letter fluency ($z=-2.45$, $p<0.05$) and category fluency for vegetables ($z=2.64$, $p<0.05$) (Table 5.8). The performance of ME/CFS participants and COVID control participants was significantly poorer than the performance of healthy participants on letter fluency only ($z=5.66$, $p<0.001$ and $z=2.04$, $p<0.05$, respectively). Finally, there was only one significant difference between COVID control participants and ME/CFS participants. The letter fluency performance of ME/CFS participants was significantly poorer than the letter fluency performance of COVID control participants ($z=-6.61$, $p<0.001$).

To establish if there is a relationship between cognitive functions measured by means of immediate and delayed verbal recall (tests 1 and 12) and letter fluency (test 5) on the one hand and informativeness during discourse production (tests 2, 4 and 8) on the other hand, Spearman's rank correlation coefficients were calculated. For healthy participants, there was a small to moderate correlation between immediate recall and flowerpot narration ($r=0.46$) and between delayed recall and flowerpot narration ($r=0.38$). For COVID experimental participants, there was a small correlation between letter fluency and flowerpot narration ($r=0.33$). For COVID control participants, there was a moderate to large correlation between immediate recall and flowerpot narration ($r=0.70$) and between delayed recall and flowerpot narration ($r=0.67$). There was a moderate correlation between delayed recall and flowerpot narration ($r=0.58$) in L2 English COVID participants. There was a small to moderate correlation between letter fluency and Cookie Theft picture description ($r=0.40$) and a moderate correlation between letter fluency and flowerpot narration ($r=0.60$) in L2 English healthy participants.

5.4 Discussion

Speech, language, swallowing, and cognitive problems are well-recognised sequelae of infectious disease in children and adults (Cummings 2019). It is therefore not surprising that dysarthria, dysphagia, and cognitive and language disorders are reported in adults with severe COVID disease requiring hospitalisation (Dawson et al. 2020; Ellul et al. 2020; Priftis et al. 2020, 2021). What is remarkable, however, is that the adults in this study, who were not hospitalised and had milder forms of infection, also present with marked cognitive-linguistic difficulties.

Moreover, these difficulties were evident many months after the onset of COVID illness when one might expect any cognitive-linguistic disturbance related to acute infection to have resolved. Whilst there has been some evidence to date of cognitive deficits in people who have recovered from COVID infection (Hampshire et al. 2021) and in people with Long COVID (Graham et al. 2021), this is the first study to find evidence of specific language deficits in individuals with Long COVID (see also Cummings 2021b).

A clear finding of this study is that adults with Long COVID have reduced discourse informativeness. The informativeness of spoken discourse in participants with Long COVID was significantly reduced relative to healthy participants in the study, COVID participants who did not report cognitive deficits ("brain fog"), and participants with ME/CFS. This latter finding suggests that reduced informativeness is not a consequence of the performance limitation that extreme fatigue in Long COVID can place on cognitive processing. Although reduced informativeness was evident in COVID participants who are native speakers of English, it was not a feature of COVID participants in the study who speak English as a second language. This latter finding may simply be a consequence of the small number of participants in the two L2 English groups or the heterogeneity in the linguistic backgrounds of the L2 English participants in the study. It would be interesting to repeat this investigation with much larger groups of L2 English participants of similar language backgrounds to establish if this result still obtains.

The reduction in informativeness increased incrementally with the cognitive challenge of the discourse production tasks used in the study. The smallest decrement in informativeness was found in the Cookie Theft picture-description task, a task in which participants were required to generate an informative description based on a single scene whilst in receipt of pictorial support. Informativeness was more compromised during the Flowerpot Incident narration, a task during which participants had to integrate information across a sequence of six pictures, also whilst in receipt of pictorial support. This integration could only be achieved if participants were able to draw inferences that linked events and characters in the story. The need to undertake temporal and causal inferences, present events in the correct order or sequence, and relate characters' actions to their motivations and mental states placed greater cognitive demands on the narrator than those required to generate a description based on a single scene. Finally, informativeness was most compromised during Cinderella narration. Where Cookie Theft picture description and Flowerpot Incident narration made few demands on memory – participants viewed pictures throughout these tasks – the narration of the Cinderella story in the absence of pictures placed considerable demands on memory. Also, the number of events and characters in this task well exceeds those in the other discourse production tasks. This greater informational load and high demand on memory surpassed the cognitive capacities of most COVID participants in the study, with a significant decrease in their informativeness during this

task as a result. Moreover, this decrease appeared not to be mitigated by the inevitable priming that is achieved when the mental script of a well-known fictional narrative like the Cinderella story is activated.

A question of some interest is why this reduced informativeness is occurring during discourse production by the COVID participants in the study. It is not on account of any structural language deficits on the part of these participants. Individuals with Long COVID were able to produce well-formed and meaningful language. This was indicated not only by their performance during spontaneous conversation but also by their sentence-generation and confrontation-naming scores, which were the same as those of healthy participants in the study. COVID participants had access to the grammatical structures and lexical repertoire that was required to produce informative discourse. Instead, the difficulties with informativeness of these participants lie squarely within the underlying cognitive skills that are required to generate informative discourse. Speakers draw on these cognitive skills to foreground some information and leave other information implicit in the background of a story, to sequence information so that the hearer can construct a coherent mental representation of the events in a story, and to explain the actions of characters through causal, temporal, and mental state inferences. The demands of this high-level information processing on memory and other cognitive abilities such as executive functioning are considerable. It is decreased efficiency of the cognitive skills that permit these high-level discourse processes to come about that is responsible for the reduced informativeness of people with Long COVID in the study. This point warrants further examination.

The production of informative discourse involves a complex array of cognitive-linguistic processes. To produce an informative story, a speaker must establish what a hearer does not know and must be told explicitly (equally, what a hearer already knows and does not need to be told). The attribution of knowledge (and ignorance) to the mind of a hearer involves *theory of mind* skills. During spoken discourse, speakers also strive to present information in a manner that can be readily assimilated by the hearer. Hearers can achieve better comprehension of discourse when they are told events in the order in which they occurred. If John crashed his car and then phoned the police, it is not facilitative of comprehension for a hearer to be told first that John phoned the police and only much later that he crashed his car. The ordering or sequencing of information occurs during our planning of discourse and uses *executive function* skills. A skilled narrator must also know how to introduce characters into a story and make subsequent reference to them through use of pronouns. If this introduction is performed poorly (e.g., the narrator says *"The king wants a wife for his son"* when there is no prior mention of the king) or if pronominal reference is used inadequately (e.g., the pronoun "she" is used when it is not clear if the intended referent is *Cinderella*, the *wicked stepmother*, or the *fairy godmother*), a hearer cannot track characters over consecutive

utterances. Certain linguistic selections must occur alongside cognitive skills like mental state reasoning for a speaker to introduce characters into a story and for a hearer to succeed in tracking them.

When these different cognitive-linguistic skills come together smoothly, a speaker can achieve a high level of discourse informativeness. When they break down, discourse informativeness is compromised to a greater or lesser extent. To illustrate the reduced informativeness of the COVID participants in the study, consider the following Cinderella narrative produced by a male participant aged 36.9 years. He was 7.7 months post onset of symptoms:

Cinderella narrative:

> Cinderella (.) is walking with her horse to a well she meets a man (0.2) she then goes only cos I know the story goes home er and the (.) wicked mother and ugly sisters are there she has to work (.) doing the menial jobs such as the sweeping (.) she's friends with the animals (.) uhm (.) they're mean to her and they (.) tear apart her (.) clothing (.) er she goes (.) to the ball (.) meets the fairy godmother (.) who (.) gives her glass slippers and uses magic to turn her into a (.) to enable her to wear a beautiful dress she meets prince charming she has to leave her slipper falls off her foot on the stair (.) she (0.2) meets him again (.) and they get married.

This participant produced 13 of 50 essential propositions and obtained an informativeness score of 26%. His performance on this narrative-production task fell between 3 and 4 standard deviations below the mean score of healthy participants in the study. This speaker's reduced informativeness can be explained as follows. He omits considerable information. There is no mention of the circumstances that led to Cinderella living with her stepmother and stepsisters, why the ball was organised, and where it was held. We are not told why or when Cinderella must leave the ball – she must leave because the spell will be broken at midnight – or that a search was launched to find the owner of the glass slipper. As well as omitting information, the speaker with COVID relates events in the wrong order. He states that Cinderella meets the fairy godmother *after* she goes to the ball when, in fact, she meets her *before* she attends the ball. The fairy godmother and her magic spell must be presented first in the story for Cinderella to have the clothing and transport that she needs to attend the ball.

This participant also displays some anomalies in his use of pronominal reference. A hearer will identify the noun phrase *the animals* as the intended referent of the pronoun *they* in line 4. This noun phrase is, after all, proximal to the pronoun. However, the *actual* referent is the distal noun phrase *the wicked mother and ugly sisters* in lines 2 and 3. This potential misunderstanding on the part of the hearer will likely be resolved as more information is presented by the speaker – it becomes

increasingly apparent from context that the pronoun refers to the stepmother and stepsisters and not to the animals. However, the speaker should avoid the need for the hearer to revise his assignment of a referent to the pronoun by using a construction that contains an explicit noun phrase:

> the (.) wicked mother and ugly sisters are there she has to work (.) doing the menial jobs such as the sweeping (.) she's friends with the animals (.) uhm (.) **the stepmother and stepsisters** are mean to her and they (.) tear apart her (.) clothing [. . .]

It is contended that the reduced informativeness of speakers with Long COVID in this study has its basis in cognitive dysfunction and is not a primary language impairment. In this connection, it is interesting to note that letter fluency (a measure of executive function) and immediate and delayed verbal recall were also areas of marked difficulty in the performance of participants with Long COVID in the study. The performance of COVID experimental participants in letter fluency and verbal recall was significantly poorer than these same cognitive areas in healthy participants, COVID control participants, and participants with ME/CFS (immediate and delayed recall only). Moreover, whilst there was a small to moderate correlation between immediate recall and flowerpot narration (r=0.46) and between delayed recall and flowerpot narration (r=0.38) in healthy participants, and a moderate to large correlation between immediate recall and flowerpot narration (r=0.70) and between delayed recall and flowerpot narration (r=0.67) in COVID control participants, the opposite pattern was evident for COVID experimental participants: there was no correlation between immediate and delayed recall and flowerpot narration and a small correlation between letter fluency and informativeness during flowerpot narration (r=0.33). It is possible that in COVID participants with cognitive-linguistic difficulties, cognitive and language functions that were highly integrated pre-COVID were operating less efficiently following COVID-19 infection. Cognitive performance in areas like executive function has been found to be associated with measures of discourse informativeness in earlier studies (Coelho et al. 1995; Mozeiko et al. 2011). The findings of the current study are consistent with this earlier work and point to a cognitive basis of this discourse difficulty in people with Long COVID.

Fatigue was consistently reported amongst the participants with Long COVID in this study (see Figure 5.2 in Appendix). It is well known that fatigue can serve as a performance limitation on language and cognition. To determine if this factor was contributing to the cognitive-linguistic difficulties of adults with Long COVID, a group of participants with ME/CFS was included in the study. ME/CFS is another clinical condition in which sufferers experience debilitating fatigue. Except for letter fluency, the performance of the ME/CFS participants on the tasks in the study did not differ significantly from that of healthy

participants. Meanwhile, the ME/CFS participants performed significantly better than COVID experimental participants on tests of immediate and delayed recall and informativeness during Cinderella narration. Although the ME/CFS control group was comparatively small, these findings suggest that fatigue may not be playing a significant role in the cognitive-linguistic difficulties of adults with Long COVID in this study.

5.5 Implications

This study found evidence of cognitive-linguistic difficulties in adults with Long COVID. These adults initially experienced mild-to-moderate COVID infection that did not require hospitalisation. Despite this fact, they had significant cognitive-linguistic difficulties in three areas: immediate and delayed verbal recall; verbal fluency (letter and category); and discourse informativeness. Moreover, these difficulties were evident on average 351 days, or 11 months, after the onset of their COVID symptoms. This time span far exceeds the 12 weeks that is used to diagnose the Long COVID syndrome and suggests that the symptom referred to as "brain fog" is a particularly persistent feature of the post-COVID 19 condition.

It is important to acknowledge that people with Long COVID who participated in the study probably presented with milder cognitive-linguistic difficulties than those found in the wider population of Long COVID sufferers. Many COVID participants had wanted to take part earlier in the study but were too unwell to do so. By the time they came forward to participate, they had already experienced considerable improvement of their cognitive-linguistic difficulties. If these same participants had been assessed several months earlier, it is likely that their cognitive-linguistic problems would have been more severe still. These same remarks apply with equal relevance to the ME/CFS participants in the study. Many people with ME/CFS are too debilitated by their condition to participate in research studies. Consequently, the ME/CFS participants who participated in the study are also likely to have milder difficulties than the ME/CFS population in general (but even then, their letter fluency performance was significantly weaker than that of healthy participants). It is likely that both groups of participants occupy the milder end of a spectrum of cognitive-linguistic difficulties which also has more severe manifestations.

Participants with Long COVID in this study had significant problems with discourse informativeness even as their structural language skills were intact. They could generate well-formed sentences and name pictures with the same degree of accuracy as healthy participants in the study. They had intact auditory verbal comprehension as evidenced by their ability to follow complex task instructions and engage in spontaneous conversation with the author. They could also convey the steps needed to perform simple, everyday tasks as well as healthy participants without COVID. These linguistic areas are problematic for speakers with aphasia where an impairment of language structure is a *primary* language disorder.

Notwithstanding their strong grammatical and lexical-semantic abilities, the adults with Long COVID in this study struggled to harness these expressive language skills to produce informative discourse. Because their discourse problems are related to cognitive difficulties, the language difficulties of adults with Long COVID are most appropriately characterised as a type of cognitive-communication disorder. Speech-language pathologists are familiar with the assessment and treatment of cognitive-communication disorders from their work with adults who have traumatic brain injury (TBI), right-hemisphere damage (RHD), and neurodegenerative conditions like Alzheimer's dementia. It is noteworthy that the production of informative discourse is also a documented difficulty in adults with these conditions (see Power et al. [2020] for TBI; Ash et al. [2017] for neurodegeneration; Marini [2012] for RHD). The results of this study suggest that we must now add Long COVID to the group of cognitive-communication disorders within a wider nosology of language disorder.

This study has several implications for the clinical management of people with Long COVID. First, the cognitive-linguistic difficulties of the adults with Long COVID in this study were sufficiently limiting to affect the ability of 93.48% of them to undertake work duties. These difficulties often persisted long after physical symptoms such as breathlessness and heart palpitations had improved. Occupational health assessments must address cognitive-linguistic issues, and Long COVID clinics must support individuals who have these difficulties. Positive steps in this direction include the recommendation to undertake neurocognitive assessment in people with Long COVID based on a recent Delphi study conducted amongst primary and secondary care doctors (Nurek et al. 2021). Second, the presence of cognitive-linguistic difficulties in adults with Long COVID suggests a need for the inclusion of speech-language pathologists and neuropsychologists in the multidisciplinary teams that are involved in the rehabilitation of these clients. These teams will lack the necessary expertise to manage individuals with Long COVID if they limit their membership to medical professionals in fields like respiratory medicine and neurology.

Third, the language difficulties of adults with Long COVID in this study were revealed through discourse production tasks such as Cinderella narration. They would not have come to light if these adults had been assessed using standardised language batteries such as the Boston Diagnostic Aphasia Examination (Goodglass et al. 2001). Many participants in the study expressed frustration that they had undergone cognitive assessments by neurologists and others, only to be told that their cognitive skills were in the normal range. This was not consistent with the difficulties that they were experiencing, with many participants reporting that their cognitive-linguistic problems had an adverse impact on all aspects of their lives. It appears likely that clinicians will need to adopt more sensitive tools of assessment if they are to succeed in identifying cognitive-linguistic difficulties of adults with Long COVID and "brain fog."

5.6 Summary

This study has found that adults with Long COVID who report "brain fog" have significant cognitive-linguistic difficulties. The performance of adults with Long COVID in this study on several language tasks was significantly weaker than the performance of healthy participants, participants with COVID who do not report brain fog, and participants with ME/CFS. These difficulties were present many months after the onset of COVID symptoms and occurred in people who initially had mild to moderate illness. The adults with Long COVID in this study exhibited reduced informativeness in discourse alongside problems with verbal fluency (letter and category) and immediate and delayed verbal recall. Their structural language skills remained largely intact. These difficulties do not appear to be related to fatigue in Long COVID but are a consequence of cognitive problems. Reduced discourse informativeness is a well-recognised linguistic feature of adults with cognitive dysfunction related to TBI, RHD, and neurodegeneration. Consistent with the diagnostic terminology used of these adults, the cognitive-linguistic difficulties of adults with Long COVID are most appropriately classified as a cognitive-communication disorder.

Acknowledgements

The author would like to acknowledge Dr Phoebe Lin, Department of English and Communication, The Hong Kong Polytechnic University, for her statistical work on this chapter. Her contribution is very gratefully acknowledged.

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APPENDIX

TABLE 5.1 Characteristics of study participants

Study group	*N*	*Age (mean)*	*Age (range)*	*Gender (M/F)*	*Education (years)*
COVID experimental participants	69	49.1 years	24.0–64.3 years	5 M/64 F	29 under 17 years 40 over 17 years
COVID control participants	11	46.5 years	30.9–60.6 years	3 M/8 F	4 under 17 years 7 over 17 years
ME/CFS participants	11	49.2 years	29.3–64.8 years	1 M/10 F	5 under 17 years 6 over 17 years
Healthy participants	26	48.2 years	18.1–64.6 years	10 M/16 F	7 under 17 years 19 over 17 years
L2 English COVID participants[1]	12	43.2 years	31.2–62.8 years	0 M/12 F	2 under 17 years 10 over 17 years
L2 English control participants[2]	13	38.3 years	18.3–60.8 years	3 M/10 F	1 under 17 years 12 over 17 years
TOTAL	142	47.3 years	18.1–64.8 years	22 M/120 F	48 under 17 years 94 over 17 years

[1] First languages of participants: Mandarin Chinese; Dutch; Romanian; Polish; Portuguese; Italian; Shona (Zimbabwe)

[2] First languages of participants: Mandarin Chinese; Cantonese Chinese; French; Spanish; Dutch

TABLE 5.2 Occupational status and pre-COVID lifestyle of COVID participants

Occupational status		*Pre-COVID lifestyle*		
Role	*%*	*Lifestyle question*	*YES*	*NO*
Administration	5.4%	Did you have chronic health problems before COVID-19?	53.3%	46.7%
Business	6.5%			
Creative industries	3.3%	Did you have a normal body weight for your age, gender, and height before COVID-19?	53.3%	46.7%
Education	21.7%			
Emergency workers	4.4%	Pre-COVID, did you consume alcoholic beverages?	67.4%	32.6%
Finance	5.4%			
Health, social care, and medicine	33.7%	Pre-COVID, did you smoke or vape?	5.4%	94.6%
Retail	1.1%			
Research	2.2%	Pre-COVID, did you take exercise?	79.4%	20.6%
Retired	2.2%			
Unemployed	7.6%	Pre-COVID, did you eat a well-balanced diet?	85.9%	14.1%
Wellness and coaching	5.4%			
Other	1.1%			

TABLE 5.3 The test and diagnostic status of COVID participants

	Antibody	*PCR test*	*Antibody & PCR test*	*Clinical diagnosis*
COVID experimental Participants	14	13	3	39
COVID control Participants	1	2	1	7
L2 English COVID Participants	5	1	0	6
TOTAL	20	16	4	52

TABLE 5.4 Mean and standard deviation (SD) for all tasks and participants

	Healthy	*COVID control*	*COVID exp*	*L2 COVID*	*L2 healthy*	*ME/CFS*
Test 1	9.73	10.45	7.77	7.96	8.62	9.05
Immediate recall	(1.97)	(1.59)	(2.01)	(2.45)	(1.99)	(1.37)
Test 2	7.79	7.77	6.9	5.96	6.69	7.14
Cookie Theft picture	(1.27)	(0.9)	(1.43)	(1.99)	(1.15)	(1.42)
Test 3	5.23	5.45	5	3.75	4.69	4.82
Sentence generation	(0.86)	(0.82)	(1.03)	(1.42)	(1.11)	(0.6)
Test 4	13.85	12.82	12.3	11.29	12.42	13.23
Flowerpot narration	(2.94)	(2.94)	(2.73)	(2.38)	(1.79)	(3.39)

(Continued)

TABLE 5.4 (Continued)

	Healthy	*COVID control*	*COVID exp*	*L2 COVID*	*L2 healthy*	*ME/CFS*
Test 5	48.08	53.27	37	31.25	37	34.45
Letter fluency	(10.85)	(14.45)	(11.51)	(9.49)	(10.32)	(11.17)
Test 6	25.81	23.45	21.74	18.17	18.69	23.82
Animal fluency	(4.72)	(6.68)	(6.68)	(3.81)	(4.7)	(6.37)
Test 7	15.31	17.18	15.16	14.17	10.46	16.18
Vegetable fluency	(3.73)	(3.46)	(4.42)	(4.26)	(3.26)	(2.99)
Test 8	32.1	31.82	26.91	32	34.23	30.59
Cinderella narration	(5.77)	(5.15)	(7.03)	(7.98)	(5.93)	(7.91)
Test 9	6.69	6.82	6.46	5.04	4.65	6.68
Sandwich making	(0.98)	(0.98)	(0.99)	(0.92)	(0.94)	(1.31)
Test 10	6.58	7.27	6.29	6.21	6.12	6.82
Letter writing	(1.42)	(1.42)	(1.32)	(1.03)	(1.42)	(1.23)
Test 11	17.62	18.27	17.71	13.75	13.15	18.73
Confrontation naming	(2.08)	(1.35)	(1.84)	(3.33)	(4.1)	(1.1)
Test 12	9.38	9.77	6.51	7.25	8.42	8.86
Delayed recall	(2.08)	(1.98)	(2.21)	(3.14)	(1.88)	(1.91)

TABLE 5.5 Test performance of COVID experimental participants vs. healthy participants

Test	*coefficient*	*standard error*	*z value*	*p-value*
Test 1 Immediate recall	−0.23	0.05	−4.18	**0.00**
Test 2 Cookie theft picture	−0.12	0.06	−2.03	**0.04**
Test 3 Sentence generation	−0.05	0.10	−0.45	0.66
Test 4 Flowerpot narration	−0.12	0.04	−2.65	**0.01**
Test 5 Letter fluency	−0.26	0.03	−7.49	**0.00**
Test 6 Animal fluency	−0.17	0.05	−3.69	**0.00**
Test 7 Vegetable fluency	−0.01	0.06	−0.16	0.87
Test 8 Cinderella narration	−0.18	0.03	−5.98	**0.00**
Test 9 Sandwich making	−0.03	0.06	−0.55	0.58
Test 10 Letter writing	−0.04	0.06	−0.70	0.48
Test 11 Confrontation naming	0.01	0.05	0.10	0.92
Test 12 Delayed recall	−0.37	0.06	−6.47	**0.00**

TABLE 5.6 Test performance of COVID experimental participants vs. COVID control participants

Test	*coefficient*	*standard error*	*z value*	*p-value*
Test 1 Immediate recall	−0.30	0.07	−4.09	**0.00**
Test 2 Cookie theft picture	−0.12	0.08	−1.43	0.15
Test 3 Sentence generation	−0.09	0.14	−0.62	0.53
Test 4 Flowerpot narration	−0.04	0.06	−0.64	0.52

Test	*coefficient*	*standard error*	*z value*	*p-value*
Test 5 Letter fluency	−0.36	0.05	−7.96	**0.00**
Test 6 Animal fluency	−0.08	0.07	−1.13	0.26
Test 7 Vegetable fluency	−0.13	0.08	−1.58	0.11
Test 8 Cinderella narration	−0.17	0.04	−4.06	**0.00**
Test 9 Sandwich making	−0.05	0.09	−0.60	0.55
Test 10 Letter writing	−0.15	0.09	−1.69	0.09
Test 11 Confrontation naming	−0.03	0.08	−0.41	0.68
Test 12 Delayed recall	−0.41	0.08	−5.33	**0.00**

TABLE 5.7 Test performance of COVID experimental participants vs. ME/CFS participants

Test	*coefficient*	*standard error*	*z value*	*p-value*
Test 1 Immediate recall	−0.15	0.08	−1.97	**0.05**
Test 2 Cookie theft picture	−0.03	0.09	−0.39	0.70
Test 3 Sentence generation	0.04	0.15	0.25	0.80
Test 4 Flowerpot narration	−0.07	0.06	−1.14	0.25
Test 5 Letter fluency	0.07	0.06	1.29	0.20
Test 6 Animal fluency	−0.09	0.07	−1.36	0.17
Test 7 Vegetable fluency	−0.07	0.08	−0.80	0.42
Test 8 Cinderella narration	−0.13	0.04	−3.06	**0.00**
Test 9 Sandwich making	−0.03	0.09	−0.37	0.71
Test 10 Letter writing	−0.08	0.09	−0.91	0.36
Test 11 Confrontation naming	−0.06	0.08	−0.74	0.46
Test 12 Delayed recall	−0.31	0.08	−3.89	**0.00**

TABLE 5.8 Test performance of L2 English COVID participants vs. L2 English healthy participants

Test	*coefficient*	*standard error*	*z value*	*p-value*
Test 1 Immediate recall	−0.08	0.10	−0.81	0.42
Test 2 Cookie theft picture	−0.12	0.11	−1.03	0.30
Test 3 Sentence generation	−0.22	0.20	−1.14	0.25
Test 4 Flowerpot narration	−0.10	0.08	−1.16	0.25
Test 5 Letter fluency	−0.17	0.07	−2.45	**0.01**
Test 6 Animal fluency	−0.03	0.09	−0.31	0.76
Test 7 Vegetable fluency	0.30	0.12	2.64	**0.01**
Test 8 Cinderella narration	−0.07	0.05	−1.37	0.17
Test 9 Sandwich making	0.08	0.13	0.62	0.53
Test 10 Letter writing	0.02	0.11	0.13	0.89
Test 11 Confrontation naming	0.04	0.11	0.41	0.68
Test 12 Delayed recall	−0.15	0.10	−1.48	0.14

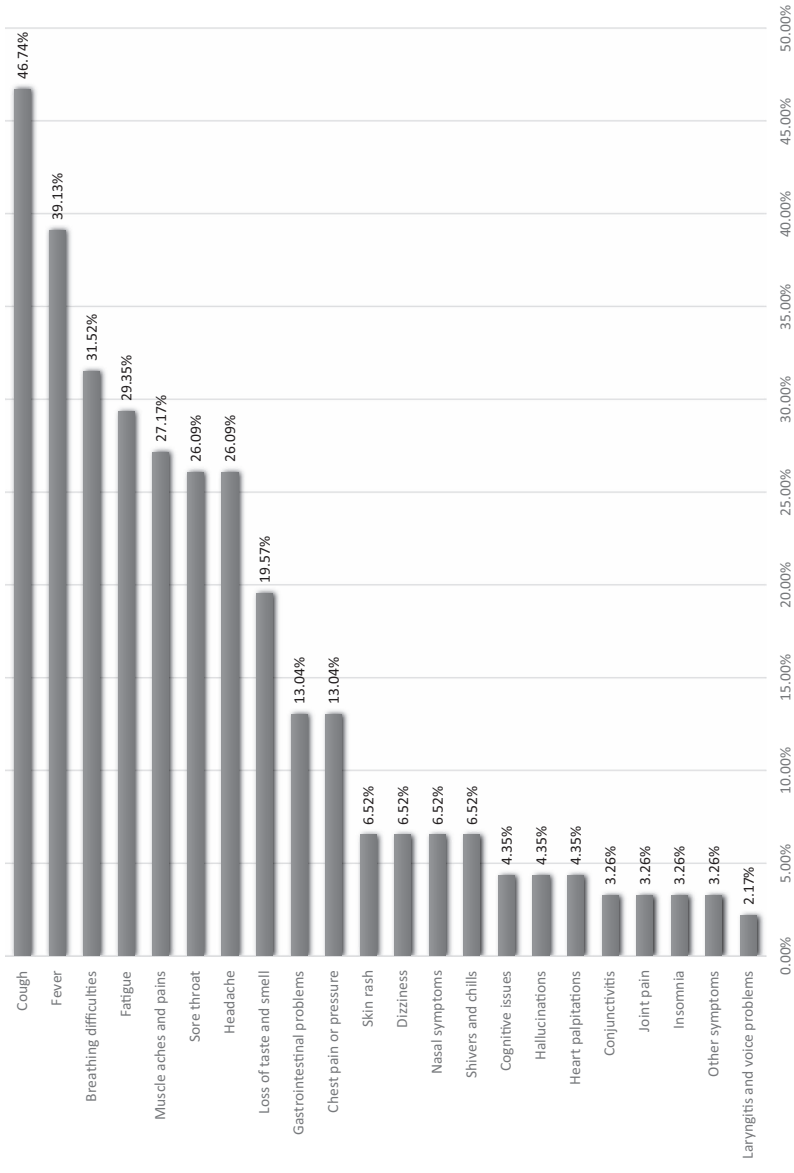

FIGURE 5.1 Symptoms at COVID onset for the 92 participants with COVID in the study

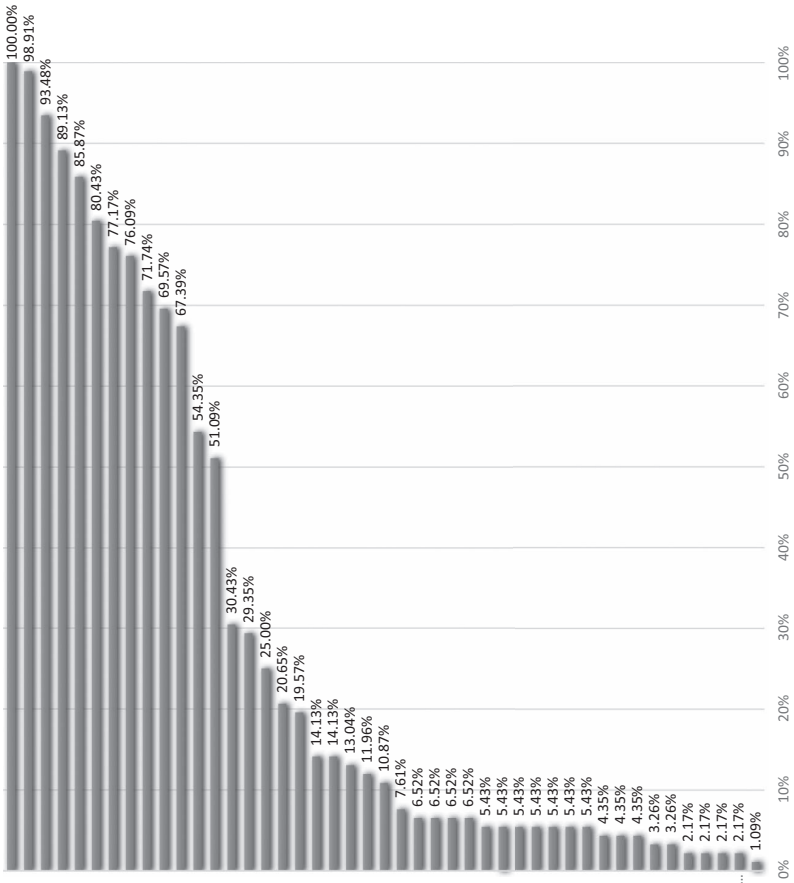

FIGURE 5.2 Overall COVID symptoms for the 92 participants with COVID in the study