Covid-19 and Language: A Case Study

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Abstract:

The emergence of novel SARS-CoV-2 has had devastating consequences for populations in all parts of the world. The virus that causes Covid-19 has resulted in high mortality, particularly among vulnerable individuals. It has also given rise to a condition termed "long Covid". This is a constellation of often debilitating symptoms that persists for many months after initial infection with SARS-CoV-2. Many adults with long Covid report an array of cognitive-linguistic difficulties that are commonly characterized as "brain fog". These difficulties compromise daily activities and occupational functioning, and cause considerable psychological distress, with many affected individuals unable to work months after the acute phase of their illness. This case study examines a 61-year-old man who contracted SARS-CoV-2 in the early days of the first wave of the pandemic in the UK. It explores in detail the development of his illness over several months. A detailed analysis of his language is undertaken. It reveals a speaker with intact structural language skills and normal speech production abilities. However, there was an impairment of high-level language skills that affected the informativeness of his discourse. The paper concludes with a brief discussion of the clinical implications of this case.

1. Introduction

The Covid-19 pandemic has swept the globe with alarming speed and ferocity since it first came to global prominence in December 2019. Its consequences for human health have been devastating. The World Health Organization estimated that the novel viral pathogen that causes this disease – SARS-CoV-2 – was responsible for the deaths of 3,311,780 million people by 12 May 2021. Even apart from deaths, there is a significant burden of illness and disability in people who survive Covid disease. In a study of 384 patients (mean age 59.9 years) with Covid infection followed a median 54 days post discharge, persistent breathlessness, cough, fatigue, and depression were reported in 53%, 34%, 69% and 14.6%, respectively (Mandal *et al.,* 2020). Among 143 Italian adults (mean age 56.5 years) assessed an average of 60.3 days after onset of their first Covid-19 symptoms, only 18 (12.6%) were completely free of any Covid-19 related symptom. A further 32% of patients had one or two symptoms and 55% had three or more symptoms (Carfì *et al.,* 2020). Of relevance to language is the fact that neurological symptoms are also a feature of Covid-19 infection. Many of these symptoms also persist long after acute infection. Neurological symptoms include anosmia (loss of smell), stroke, paralysis, cranial nerve deficits, encephalopathy, delirium, meningitis, and seizures (Fotuhi *et al.,* 2020).

As people began to describe their protracted recovery from Covid-19 infection, expressions like "brain fog" were coined to capture a group of unseen difficulties that were causing significant distress to individuals who experienced them. This expression covered an array of cognitive and linguistic problems such as memory loss, word-finding difficulties, poor concentration, and difficulty following and remembering a topic of conversation. People with long Covid articulate these difficulties in considerable detail:

54-year-old woman; 11 months post onset:
"I am easily distracted, unless I am on a task that requires all my concentration"

64-year-old woman; 7 months post onset:

"I have had to pause and allow other people to suggest the word I am so obviously looking for"

31-year-old woman; 8 months post onset:
"I lose track of my thought process and struggle to find the right word, or I use the wong one without realising it"

These self-reports prompted me to start investigating what impact, if any, long Covid might have on language skills. Although language disorders like aphasia were beginning to be reported in people with Covid disease, these studies were undertaken in seriously ill patients who were hospitalised (Muccioli *et al.,* 2020; Priftis *et al.,* 2020). I was interested in studying those individuals who had moderate Covid illness but who had still not made a good recovery from their illness. These people had started to organise themselves on Facebook support groups dedicated to long Covid and Covid long-haulers and were actively discussing and comparing the symptoms that they were still experiencing many months after their initial infections. The presence of "brain fog" was prominent among these symptoms. I approached the managers of these Facebook groups and discussed the type of work that I was undertaking. It was not long before people started to approach me to take part in my study.

The case study discussed in the next section is part of a study of 35 adults with long Covid. The results of this study are reported in detail elsewhere (Cummings, 2021, 2022). The mean age of these adults was 47 years. They ranged in age from 24 to 64 years. There were 4 men and 31 women in the study. Nine participants had under 17 years of formal education and 26 participants had over 17 years of education (see Figure 1 in Appendix). All participants enjoyed good health before contracting SARS-CoV-2. None of these participants with Covid-19 was judged to be ill enough to warrant extended hospitalisation. However, many attended Accident and Emergency departments or had 1- or 2-day hospital stays for support with their symptoms, particularly respiratory and cardiac symptoms. It is worth remarking that the decision not to admit these individuals to hospital wards was related in many cases to the parlous condition of medical facilities at the beginning of the pandemic in the UK, Europe and

USA, and should not be taken as a sign that the symptoms that these individuals experienced were all minor in nature.

Several participants in the study are medical and health professionals. Some had become infected with SARS-CoV-2 through direct contact with infected patients who were in their care. This occurred most often at the start of the pandemic when personal protective equipment was inadequate and was in short supply. The 61-year-old man who is the focus of the following case study is a genetic pathologist. His exposure to the virus was not related to his work as he does not interact directly with patients. He was chosen for a case study because of his medical background. His medical knowledge enabled him to give a very detailed account of the onset and progression of his illness as well as its impact on both his physical health and cognitive functioning. In keeping with Covid restrictions, all participants in the study were recorded online via Zoom or Skype. Two control groups of 17 healthy participants and 6 Covid participants with no self-reported cognitive-linguistic difficulties were also included in the study (see Figure 1 in Appendix).

All participants in the study were recorded online as they undertook a total of 12 language tasks. Each participant was asked to recall a 100-word spoken narrative called Sam and Fred, both immediately and at the end of the session. This task examined immediate and delayed recall of verbal material. The ability to produce words beginning with the letters F-A-S and to generate the names of animals and vegetables, all in 60 seconds, was used to test letter (phonemic) fluency and category (semantic) fluency, respectively. Sentence generation was examined by giving participants two, three, and four words and asking them to put them into brief spoken sentences. Participants were asked to name 20 pictured items in a test of confrontation naming. The ability to characterise steps or stages in everyday activities (procedural discourse) was assessed by asking participants to describe how they would make a cheese and ham sandwich and write a letter to someone. The Cookie Theft picture from the Boston Diagnostic Aphasia Examination (Goodglass *et al.*, 2001) was used to assess picture description ability. A six-frame set of black-and-white line drawings called the Flowerpot Incident, and the Cinderella story were used to examine narrative production under different

conditions of production. For further details on each of these tasks, the reader is referred to Cummings (2020a).

2. Case study

Background: Peter (not his real name) is 61;8 years old. He is married and has a 23-year-old daughter. Prior to his retirement from the UK's National Health Service (NHS) in 2019, Peter was a Consultant in Genetic Pathology. He obtained his degree in medicine in 1980 and a PhD in DNA Repair in 1995. During his medical career, Peter was a Member and later a Fellow of the Royal College of Pathologists and a Fellow of the European Board of Laboratory Medicine. He is still very active within medicine, with several clinical and research roles and professional appointments in his portfolio. Although work has been a very significant part of Peter's life, he acknowledges that it has not always led to a healthy work-life balance. Since relinquishing his role as Laboratory Director in 2012 and retiring from the NHS in 2019, he has had more time to pursue other interests. He expects this to improve further when he retires fully from medicine in around 2024. Peter's wife is a Professor of Cellular Immunology and Immunotherapy in a university in the UK.

Prior to contracting Covid-19, Peter enjoyed reasonably good health. He weighs 97Kg and his height is 1.80m, giving him a BMI of 29.9. This places him in the overweight but not obese category. At around 16 years of age, Peter started to develop migraines. Attacks lasted a day and occurred once or twice a fortnight. They resolved spontaneously in his early twenties. In 2001, Peter had a laparoscopic cholecystectomy. Although the operation itself went well, he experienced a serious haemorrhage after the procedure, losing 4-5 units of blood over an 8-hour period. Some 10 years after his cholecystectomy, Peter developed acute pancreatitis when a stone formed in his common bile duct. This was successfully treated. At 51 years of age, Peter developed glandular fever (Epstein-Barr virus). He took a year to recover fully. Peter takes several prescribed medications (see *Medication*) and is allergic to Penicillin.

Peter wears hearing aids for noise-induced hearing loss caused by pistol and rifle target shooting. He used to be myopic and anastigmatic. In 2012, he had laser corneal surgery. Peter

has never smoked or vaped. He very occasionally consumes small quantities of alcohol, amounting to around 6 units per year. He has a well-balanced diet, although thinks he could maybe eat a bit less in general. Since 2019, he has taken Vitamin D supplements in the winter months. Peter does not take regular exercise but occasionally does hill walking. His other interests include model making and model railways and reading books on militaria, transport and industrial history. He meets friends regularly, mostly while shooting.

On 3 March 2020, Peter experienced malaise, fever and headache. He did not think these symptoms were related to Covid-19, attributing them instead to a gashed knee that he sustained while gardening on 1 March 2020. He had to attend Accident & Emergency for this injury, where he received 12 stitches and a tetanus booster. This seemed to be a reasonable explanation of his symptoms, given that at the time there were only two positive cases of Covid-19 recorded in the part of the UK where he lived, and each was 40km away. On 8 March 2020, Peter developed coughing. This marked the start of a wide range of mostly severe symptoms that extended for several weeks (see *Clinical Symptoms*). Peter remained at home during this time. He had a telephone call with his General Practitioner on day 14 of his illness. He was the first case of Covid-19 his doctor had encountered.

Peter does not know how he was exposed to the virus. He had travelled by train to a regional capital city on 28 February 2020 to attend an audiology appointment. This was five days before the onset of his symptoms. He assumes he became infected at some point during this trip, possibly from contact with ticket barriers, use of an ATM, or consumption of a sandwich that he bought at the rail station. Peter checked with his audiologist and she did not develop Covid-19. Peter's wife also did not develop Covid-19 despite her high level of exposure to the virus. She attributed her lack of infection to pre-existing cell-mediated immunity due to previous infections with other viruses. Like many people at the start of the pandemic in the UK, Peter did not have a positive virus test. However, he had antibody tests. He had antibodies to recombinant human novel coronavirus nucleoprotein on days 21, 28, 34, 100 and 190. He also had IgG antibodies against the spike protein S1 receptor-binding domain on specific

enzyme-linked immunosorbent assay (ELISA) tests. These tests were conducted by NHS Blood & Transplant as part of convalescent plasma donation.

Since developing Covid-19, Peter has had several medical investigations and tests. On 18 July 2020, he had a chest X-ray and nothing abnormal was detected. On 27th August 2020, Peter underwent tests for the following: urea and electrolytes; C-reactive protein (protein produced by the liver that is a marker of inflammation); liver function; full blood count; thyroid and HbA1c (a test for average level of blood sugar over the past 2-3 months). Again, nothing abnormal was detected. He is currently awaiting a red blood cell magnesium test.

Clinical symptoms: It is important to distinguish between the symptoms of acute Covid-19 infection and symptoms associated with long-term illness (so-called Long Covid). Peter had several, severe symptoms in the acute phase of his illness. He had severe fever, coughing, change of taste and smell, fatigue, aches and pains, headache, chest pain/pressure and unusual sensations. Peter described the fever in his illness as "bone cracking". It was more severe than he had experienced in either influenza or Epstein-Barr virus. Peter's coughing was involuntary and was non-productive or only slightly productive. It was induced by a change of position. Initially, it occurred at night. Peter described it as "relentless", "deep seated" and "like no other" coughing he had experienced. At its worst, it induced hypoxia and fainting. It stopped on day 42 of his illness. Peter noted a change of taste and smell on day 3. It was subtle at first, with things such as coffee starting to taste unpleasant. It was associated with the onset of anorexia which lasted one week. He lost 7Kg. Between day 10 and 15, Peter experienced an hallucination of smell. He sensed a (not unpleasant) cooking smell which he put down to a blocked flue in his confusional state.

Confusion, possibly delirium, occurred at the height of Peter's fever and coughing at day 11 to 14 of his illness. He reported that he "lost a day" when he got up on a Sunday and was told by his daughter that it was Monday. He had racing thoughts about matters of no consequence. Being Scuba trained to use oxygen-enriched air, he decided to ask his wife if

she could travel to a shop, some 14 miles away, that sells diving equipment and get him a tank of 36% oxygen. He thought this would make everything alright.

Peter was profoundly fatigued during the acute phase of his illness. He had severe musculoskeletal pain which left him unable to get comfortable and sleep. Large joints, particularly the sacro-iliac joints, were very painful. He also experienced musculoskeletal pain related to coughing. "It felt like I'd pulled the muscles and my diaphragm off my ribs", he reported. Peter had constant, severe headache. He also reported parathesiae. During the first week of illness, he felt like he had a first-degree burn on his back when he put on a shirt or a pyjama top. There was no rash or even reddening of his skin. He also experienced some tingling on his forearms and the backs of his hands. This was followed by hypersensitivity of hairs on the backs of his hands for some weeks.

Peter experienced moderate breathing difficulties and gastrointestinal problems. He was able to breathe air in and out of his lungs. However, on day 12 he noticed alternating hyperventilation and hypoventilation, characteristic of Cheyne-Stokes respiration. This was a very frightening symptom for Peter who, as a medic, knows it is an extremely bad sign in an ITU setting. Between day 14 and 18, Peter experienced gastrointestinal problems. This started with upper gastrointestinal dyspepsia, then mid and lower gut cramps, and then finally constipation and diarrhoea. During the first week of his illness, Peter had mild conjunctivitis. He also experienced hypotension, especially postural hypotension, during the acute phase of illness. On several occasions, he passed out. He decided to stop taking his ACE inhibitor (see *Medication*) when he took his blood pressure and discovered it was sub-normal for him.

Peter has not yet made a full recovery from Covid-19. He describes a post-acute illness that is chronic and relapsing and in which there are significant and debilitating symptoms. One of his neighbours, a senior medic in the army, saw him in the immediate post-acute phase and again a bit later and said he did not look well. He found this reassuring as it matched exactly how he felt. After experiencing up/down cycles in his illness, Peter began to realise that his recovery might be protracted: "I'd appreciated it would be a long haul to get better".

Peter reports that he has profound shortness of breath on exertion. Even just packing bags at the supermarket can leave him breathless. He also experiences tachycardia, malaise, weakness, muscle aches, lethargy, sleep disturbance and slowness of thinking ("brain fog"). He wonders if a magnesium deficiency, known to play a role in chronic fatigue, might be contributing to these problems. He has taken a prescribed magnesium supplement (see *Medication*) but has not noticed any improvement in his symptoms. Peter describes shaky episodes when he is irritable, weak and can loose his temper. He wonders if they are hypoglycaemic in part as they can occur if he goes too long between meals and can be alleviated by sugar. However, they can also occur within a couple of hours of eating a full breakfast. His sleep is disturbed. He can go to bed tired and not sleep and wakes up early. He often has a sleep in the afternoon. He can sometimes wake in the night feeling nauseous but is unsure if this is related to his stomach or is an inner ear disturbance.

Some of Peter's symptoms are cognitive in nature. He reports how he has experienced slow mentation and recounts an episode in the supermarket where he could not decide which eggs to purchase. He reports that his ability to remember things seems worse. He now writes more lists to aid his memory. He often struggles to find words and names (see *Communication*). When Peter is in a good phase, he finds projects that he had dropped or forgotten. He might start doing something and then realise he has forgotten to attend a Zoom meeting or ring someone or has left something off a shopping list. He must now look at his diary a lot to check what is coming up.

In the acute phase of Covid-19, Peter experienced understandable feelings of fear and anxiety. During his long recovery, he has reflected on the gravity of his illness. He reports experiencing depression and emotional lability. This is how Peter characterizes the impact of Covid-19 on his mental health:

> "All this reinforcement that I narrowly escaped death is reminiscent of what
> soldiers returning from wars report: unless you've been through it, you have no

idea. I expected post-illness depression and this was made worse by the frustration of being informed as a medic and informed by "directly relevant experience" forced on me by Covid-19, and yet seeing so much incompetence, ignorance and seeming stupidity causing so much death and misery in the world. I found it hard then and still find it very emotional to see survivors on TV talking of their experiences. I can totally relate to returning soldiers not talking about their experiences, especially with people who they reckon know nothing about the experience. Having had an episode of work-related depression in 2010 to 2012, I try to be open about what I now feel as I realise people probably will not mention it."

Peter reports experiencing survivor guilt because he has survived Covid-19 where many other people have not. He must contend with uncertainty about the prospects of making a full recovery: "Am I going to get better? Have I reached the limit of my recovery?". He feels he wants to alleviate the suffering of others by donating blood plasma and contributing to research to better understand the health impact of this new virus. He also feels that people in his situation have been "left alone" and are having to look after themselves. This complex set of emotions is continually relived during his recovery.

Daily activities: Long Covid has had a profound impact on all of Peter's daily activities. He can only undertake "a fraction" of the work duties that he would like to undertake, such as conducting research and writing scientific papers and teaching articles. He tries to attend virtual committees but finds it hard to concentrate. Peter's pursuit of leisure activities has also been compromised. He was too unwell to attend shooting and missed this very much. When he was in a good phase with his symptoms, he was able to do a considerable amount of hill walking on holiday. When he is in a bad phase, he is unable to do "anything except the minimum". Peter is not able to read as much as he would like but he can still watch TV. Household chores are limited by fatigue. He enjoys cooking with his family, and would like to cook more, but the enthusiasm is often not there: "Thinking about planning to cook something can be beyond me".

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Medication: Peter takes prescribed medications every day. This includes the ACE inhibitor, Ramipril (5mg once a day), for the treatment of hypertension. He takes Atorvastatin (20mg once a day) for the reduction of cholesterol. Peter takes Aspirin (150mg once a day) to prevent blood clotting.

During his acute illness, Peter took some ibuprofen to manage his symptoms. However, he did not want to take too many non-steroidal anti-inflammatory drugs (NSAIDs) as there was some concern at the time that NSAIDs worsened the symptoms of Covid-19. He used diclofenac gel for his joint pains. He experienced hypotension at the height of his illness and stopped taking his ACE inhibitor. Peter has also used medications in the post-acute phase of his illness. He took magnesium as magnesium aspartate (20 mmol per day) for most of September 2020. He ran out of this medication and noticed no ill effects. However, he then requested a repeat prescription when he did not return to a good phase in his symptoms. When Peter's muscle aches are especially bad, he sometimes uses NSAIDs.

Communication: Peter reports that Covid-19 has had an adverse impact on his ability to communicate using spoken and written language. He often experiences "gaps" in conversation and has to fill them in with a description of the word or name that he is trying to find, e.g. "so-and-so who did that" and "that thing I was looking for yesterday". An example of this behaviour – so-called circumlocution – occurred when he was trying to describe to an engineer a repair that was needed on his tractor mower. He wanted to say that the cutting deck needs "sand-blasting" and then "powder-coating", but he was unable to produce either word combination.

Peter reports that he can "loose his thread" in conversation and can forget the point he was trying to make. He can sometimes struggle to remember what others have just said in conversation and he thinks this may in part explain why he is finding Zoom meetings difficult. Occasionally, he finds it difficult to follow what others are saying in conversation. Peter has observed a reduction in his desire to participate in conversation with others. He admits to

having to think about what he wants to talk about, even with close family members. He has a "degree of reluctance" about conversations with others such as telephone calls. He also thinks he is communicating with others less frequently than usual. He does not initiate as many calls as he did before his illness.

In terms of written language, Peter has noted that he is not reading as much as he did before his illness. If he must read something like an article, he reports that it can take him days to summon up the energy and enthusiasm to do it. He can read short books with pictures and magazine articles but is not tackling big books. When undertaking writing, it is his usual practice to let things go around in his head for several days before committing them to paper. But this thinking process has been compromised, a problem that he captures as "trouble thinking about thinking about things".

The author spoke to Peter online on 15 October 2020. The interaction took place at 9am UK time and lasted for approximately one hour and 15 minutes. Peter was alert and responsive throughout the meeting and he participated willingly in all tasks. He had a relaxed demeanour and his mood was normal. Peter spoke at ease about his career in medicine and about how his recent Covid illness had affected him. He did not require prompting from the author during conversation or any of the structured tasks and readily volunteered information and responses. Peter did not appear to fatigue during the session.

Peter's speech was fully intelligible. His articulation of speech sounds was intact, and he spoke with normal volume. Peter's oral-nasal resonance, respiratory support for speech, use of prosody and production of voice were typical of a speaker of his age and gender. Peter displayed normal speech fluency and rate. There was no evidence of dysarthria or apraxia of speech and he did not exhibit a phonological impairment.

Peter's expressive morphology was intact. He used a full range of inflectional and derivational suffixes:

Inflectional suffix:

prince's approval (*genitive*); polyp**s** (*plural*); manag**ed** (*past tense*); quiet**er** (*comparative*); look**ing** (*aspect*); earli**est** (*superlative*)

Derivational suffix:

reason**able**; mutat**ion**; profession**al**; ova**rian**; year**ly**; hand**ful**; patholog**ist**; encourage**ment**

Peter's use of prefixes was similarly diverse and expressed a range of meanings, as indicated in parentheses:

premalignant ('before')

inexperienced ('not')

misdiagnosis ('incorrect')

abnormal ('deviate from')

Peter produced and understood complex syntax. His performance on the sentence generation task was 100%. Peter's spontaneous expressive language included nominal relative clauses, passive relative clauses, and comparisons of equality, as in the following examples:

"what people tend to come to me about is interpretation of genetic variants" (*nominal relative clause*)

"when you look at people who've been subject to population screening" (*passive relative clause*)

"it's nowhere near as good as when you scope the general population" (*comparison of equality*: adjective + clause)

Peter clearly understood complex syntactic structures in the author's utterances, including interrogative subordinate clauses in questions and relative clauses in statements:

"can you describe for me what your work involved?" (*interrogative subordinate clause*)

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"this is, I suppose, the cycle <u>that we go through in our knowledge</u>" (*relative clause*)

Vocabulary and semantics were also areas of strength for Peter. He had a high-level vocabulary containing many technical words that reflected his medical background. Although Peter reported word-finding difficulties in conversation, he had no evident difficulty retrieving the words that he wanted to use. Peter did not produce semantic paraphasias or use circumlocution. He did not pause unduly or use fillers before content words. He named all items correctly during confrontation naming. Peter's category fluency performance was another area of strength. He produced 26 animal names and 17 vegetable names in 60 seconds. There were eight violations in the vegetable category, with Peter producing seven names of fruits (e.g. *apples, bananas, pear, plum, cherry*) and the name of a seed (*walnuts*). This suggested reduced inhibition and monitoring of his verbal output and might indicate some impairment of executive function were it not for Peter's letter fluency score (see below). Notwithstanding these errors, Peter's category fluency scores exceeded normative values for adults of similar age, gender, and education level (all figures are means):

Animal naming (Tombaugh *et al.,* 1999):
Age (60-69 years): 17.6 names
Gender (male): 17.4 names
Education (17-21 years): 19.5 names

Animal naming (Acevedo *et al.,* 2000):
Age (60-69 years): 17.1 names
Gender (male): 16.2 names
Education (17+ years): 18.8 names

Vegetable naming (Acevedo *et al.,* 2000):
Age (60-69 years): 14.4 names
Gender (male): 11.9 names
Education (17+ years): 14.7 names

Animal and vegetable naming (Clark *et al.,* 2016):
51 cognitively normal adults (mean age: 68.9 years)
22 animal names in 60 seconds
15 vegetable names in 60 seconds

Peter's confrontation naming and category fluency performance suggested his lexical access, retrieval and generation were largely unaffected by his Covid illness.

The same is true of Peter's expressive semantic abilities. Peter produced meaningful utterances in which clauses were related by means of conditional and temporal relations and concepts such as consequence and concession:

Condition:

"<u>if</u> we can understand people who are really prone to it, that would help us with the generality"

Time:

"<u>before</u> we did national screening […] roughly equal proportions of patients were found in stages one, two, three, and four"

Consequence:

"I'm the honorary treasurer for two, two professional organisations […] <u>so</u> there's a, there's a fair bit I think about it, about that"

Concession:

"<u>even though</u> we're scoping them every two years, it doesn't reduce the cancers they get"

Peter made skilled use of pragmatic aspects of language. He contributed relevant, informative utterances to conversation. Peter was attentive to the knowledge of his conversational partner. In the following extended turn, he suspends his utterance momentarily to provide the author with background information about bowel cancer. This suspension, which begins at ↑ and terminates at ↓, indicates a speaker who is actively contributing relevant information to his hearer's discourse context:

"yeah, yeah and the cancers that are found (.) are (.) um very much down staged as we say so (.) before we did national screening ↑ there's, there's four stages that bowel cancer can be found at there's stage one which is the earliest and stage four is metastases in the liver ↓ and that's just about yeah um and roughly equal proportions of patients were found in stages one, two, three, and four okay when you look at people who've been subject to population screening yeah (1.36) you find that the vast majority of cancers are found in stage one"

Other pragmatic aspects of language were also evident in Peter's expressive language. He undertook repair of his utterances, such as the use of self-initiated self-repair to correct the tense in the following utterance:

"there <u>was</u> a very keen surgeon, there <u>is</u> a very keen surgeon there"

Peter made skilled use of presupposition. The implicative verb in the first utterance below generates the presupposition that Peter *tried* to make all the meetings, even though he did not attend them all because of the lingering effects of his Covid illness. The factive verb in the second utterance triggers a fact as its presupposition, namely, that certain cancers are derived from lesions that do not take the form of polyps. Peter is clearly aware of the epistemic stance to which this verb's presupposition commits him (viz., claim X *is true*) and moves quickly to substantiate his claim by adding that it is supported by microscopic and molecular evidence:

"I can't <u>manage</u> to make them [meetings] all" (*implicative verb*)
"we <u>realise</u>, well to my mind that, that is evidence that's been proven microscopically and molecularly that many of their cancers are derived from lesions which are not polypy" (*factive verb*)

Peter used deixis effectively to situate himself as speaker in a wider spatial and temporal context. In the first utterance below, *there* is used to refer to a location distal to Peter as the speaker of the utterance. In the second utterance, Peter relates an event (his 'crashing out') to the time at which he expresses his utterance through the deictic expression *last night*:

"my wife can see her mother-in-law on the way <u>there</u>" (*spatial deixis*)

"<u>last night</u> I was absolutely crashed out" (*temporal deixis*)

One final pragmatic feature is noteworthy. Peter also used figurative language appropriately during conversation. This included idioms and metaphors. In the third example below, mushrooms are a vivid metaphor for the latent development and rapid appearance of polyps in the lining of the bowel:

Idiom:

"the next day the weather was good, so <u>strike while the iron's hot</u>, we thought"

"I'm the kind of <u>buck stops here</u> person"

Metaphor:

"they acquire the mutant particular gene that makes them polypy or they stay flat and then they pop up, so I'm reminded of that every autumn, because I see the little mushrooms appearing on the lawn and I know the fungus is all year in the lawn and then only now does it pop up"

Peter's language profile revealed some weaknesses in high-level discourse skills. His performance on discourse production tasks was generally poor, with reduced informativeness a feature of all the discourses he produced. Peter produced 28% of essential information units on the Cinderella story. This increased to 41% during the Cookie Theft picture description task and 67% during the telling of the Flowerpot Incident story. Peter's immediate and delayed recall of the 100-word Sam and Fred story was 60% and 42%, respectively. In each of these discourses, Peter's performance was below the mean for healthy participants. His immediate recall and Flowerpot Incident narration were within 1 standard deviation below the mean for healthy participants. His delayed recall was greater than 1 standard deviation below the mean. And his Cookie Theft picture description and Cinderella narration were greater than 3 standard deviations below the mean for healthy participants.

It is difficult to discern a clear pattern to Peter's reduced informativeness. Verbal memory appears to be a relative strength for Peter, with even his delayed verbal recall resulting in more informative discourse than the description of a picture (Cookie Theft) and the production of a fictional narrative (Cinderella), both tasks in which discourse production was supported by pictures. However, his most informative discourse was the Flowerpot Incident in which narration is based on a series of pictures. Perhaps what can be said is that Peter was most informative when he had visual support in the form of pictures and a clear sequence to follow in his narration, which are the conditions created by the sequence of pictures in the Flowerpot Incident. When he had to produce a lengthy story (not Sam and Fred) from memory and a story or description where he had to generate a discourse structure (viz., Cinderella and Cookie Theft description), his informativeness was markedly reduced.

It is instructive to examine Peter's least informative discourse, the Cinderella story, in detail. This is Peter's attempt to tell the story:

> "okay so Cinderella (1.23) um (2.56) meets, meets the prince outdoors when she's with her horse by the fountain (1.08) she's observed by (1.04) ah the nasty mother with the two ugly sisters who um clearly, sorry there's a fly in here um (1.23) clearly um disapproves of, of, of his approve of the prince's approval of her sis, of Cinderella (.) um (1.24) um she's teased Cinderella is teased in the kitchen um (1.13) ↑ there's, there's a ball that's going to happen but although the ugly sisters can go Cinderella can't of course and um Cinderella happens to be visited by her fairy godmother who tells her she can arrange this and so Cinderella turns up to the ball with her (1.12) glass slippers (.) and dances the night away and then of course has to be away by midnight um and in her hurry to be away from the ball at which thee um prince is, is, is present she leaves her glass slipper on the steps (.) and when she gets home um she's discovered as to what she's been doing so the nasty woman locks her in the cellar but in this version the mice bring the key to her because they're small enough to get through a hole I imagine um and she's able to let herself out (1.11) um (.) and (.) thee the king and his main man are

ah out looking for the (1.25) owner of the said slipper so, so um they put their feelers out and it is found that it fits Cinderella's foot (1.12) and therefore she is summoned to the palace and reintroduced to the prince and it all ends happily ever after"

The first third of Peter's narrative contains incorrect information such as that Cinderella meets the prince outdoors. Peter does not assess that Cinderella cannot possibly meet the prince at the start of the story when she meets him for the first time at the ball in the palace later in the story. Peter only begins to get his narrative on track at the point marked ↑. But even here, he does not mention why the ball is taking place – the elderly king wants his son, the prince, to find a wife. Although Peter introduces the fairy godmother, he neglects to mention the magic spell that transforms a pumpkin in the garden into an ornate carriage and Cinderella's mice friends into white horses. The prince is introduced late by Peter and only at the point when Cinderella must leave the ball. Peter does state that Cinderella gets home but does not describe how she reverts to her original attire or what happens to the carriage and horses. The final omission occurs when Peter does not state that Cinderella and the prince get married.

The reduced informativeness of Peter's Cinderella story may reflect a lack of interest in the story and attention to its details or may be a consequence of the less informative narrative style that is typical of many male speakers (Wainwright, 2019). For a person who has occupied a challenging professional role throughout his career, one demanding the ability to assimilate and reproduce complex information with accuracy, Peter's reduced informativeness is less readily explained by these factors and may reflect some impact of his Covid illness on his cognitive-linguistic skills.

Although Peter did not produce informative narrative discourse, he did at least produce cohesive narratives. In this extract from his Cinderella narrative, Peter uses two cohesive devices, namely, ellipsis (in bold) and anaphoric reference (underlining). The referents of the personal and demonstrative pronouns *her, she,* and *this* are Cinderella, the fairy godmother, and attendance at the ball, respectively:

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"there's a ball that's going to happen but although the ugly sisters can go Cinderella can't **[go]** of course and um <u>Cinderella</u> happens to be visited by her <u>fairy godmother</u> who tells <u>her</u> <u>she</u> can arrange <u>this</u>"

Peter uses lexical substitution (*one* is a substitute for *lump*) to achieve cohesion in this extract at the very end of his narration of the Flowerpot Incident:

"got a lump on his head then (.) just like the **one** I'd above my right eye when I walked into the carpark barrier that"

As well as producing cohesive discourse, Peter produced discourse that was well sequenced and organized. Events in stories were narrated in the order in which they occurred. Peter described the steps needed to perform simple everyday tasks like making a sandwich in the correct order. The correct sequencing of information was evident not just in contexts where it was supported by test stimuli (e.g. the sequence of pictures in the Flowerpot Incident narrative) but also in contexts where no such structural support was given, e.g., the Cinderella narrative where the picture booklet was closed after an initial viewing of its content. Discourse planning and organization were areas of strength for Peter and suggest that he retains intact executive function skills. The latter is also supported by Peter's letter fluency score. Peter produced 49 words beginning with F, A and S in 60 seconds (F=22 words; A=14 words; S=13 words). This score is consistent with, and in some cases exceeds, normative values for letter fluency attained by adults of the same age, gender, and education level as Peter (all figures are means):

Letter fluency (Tombaugh *et al.,* 1999):
Age (60-69 years): 38.5 words
Gender (male): 37.0 words
Education (17-21 years): 43.9 words

Letter fluency (Clark *et al.,* 2016):

51 cognitively normal adults (mean age: 68.9 years)

No. words produced in 60 seconds:

F=16.8 words; A=15.6 words; S=16.9 words

Finally, another discourse strength was Peter's ability to capture the mental states of characters in stories and pictures. The underlined words in the following utterances indicate that Peter was able to attribute a range of cognitive and affective mental states both to his own mind and to the minds of others, namely, the mother in the Cookie Theft picture and the man and his dog in the Flowerpot Incident:

Self-attribution:

"I <u>know</u> the fungus is all year in the lawn"

"I <u>think</u> that has to be the most recent one"

Other attribution:

"she hasn't <u>noticed</u> that her sink is overflowing"

"she's curiously <u>oblivious</u> to it all"

"he and his dog are not best <u>pleased</u>"

"the dog <u>appreciates</u> that"

"the dog's completely <u>satisfied</u>"

Combined with Peter's awareness during conversation of his interlocutor's state of knowledge, Peter's skilled use of mental state attribution suggests that he retains strong theory of mind abilities following his Covid illness.

COMMUNICATION PROFILE:

Speech intelligibility:

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- Peter's speech was fully intelligible. All aspects of speech production, including articulation, resonance, phonation, prosody, and respiration, were in the normal range for a speaker of Peter's age and gender. Peter's speech rate and fluency were unremarkable. He had no motor speech disorder or phonological impairment.

Morphology and syntax:

- Peter's utterances were well formed and structurally complex. He used an extensive range of prefixes and derivational and inflectional suffixes. Peter used complex syntax including nominal relative clauses, passive relative clauses, and comparisons of equality (e.g., *as + adj + as + clause*). Peter's comprehension of syntax was also an area of strength based on his understanding of the author's instructions and questions.

Vocabulary and semantics:

- Peter reports word-finding difficulties in conversation, although this was not apparent in his language sample. His confrontation naming performance was excellent (100%). There were no instances of semantic paraphasia or circumlocution in his language sample. Peter's category fluency scores for animals and vegetables exceeded normative values for people of the same age, education level and gender, although there were several category violations during the generation of vegetable names. Peter produced meaningful utterances. He expressed complex conceptual relations such as consequence and concession.

Pragmatics:

- Peter's pragmatic language skills included the use of presuppositions, figurative language (especially metaphors and idioms), and deixis. He was aware of the epistemic stance to which certain presuppositions committed him. Peter undertook repair of his utterances and contributed informative, relevant utterances to conversation. He was attuned to the knowledge of his conversational partner and suspended discourse momentarily when it

became necessary to address gaps in his hearer's knowledge. Peter made appropriate use of humour and laughter.

Discourse:

- Peter displayed reduced informativeness in monologic discourse. It was difficult to establish if this was a gender-based feature of his discourse or a feature related to his self-reported cognitive issues following his Covid illness. Peter used a range of cohesive devices, including ellipsis, lexical substitution, and anaphoric reference, to link utterances in discourse. He was able to plan and sequence events in a narrative and steps in everyday tasks.

Cognition:

- Peter's cognitive skills were not formally assessed. He did, however, report cognitive issues like slow mentation since developing Covid infection. Peter's letter fluency score for the letters F-A-S suggested that there was no impairment of his executive function skills. It was observed, however, that he failed to monitor, inhibit, and correct several errors of category membership during the generation of vegetable names. Peter displayed strong theory of mind skills during conversation and other forms of discourse. He addressed gaps in his interlocutor's knowledge when this was necessary and attributed a wide range of mental states to characters in stories and pictures.

Figure 1: Peter's communication profile

3. Implications

Peter had a very specific area of difficulty relating to the informativeness of his expressive discourse. His speech production abilities were normal. He was able to produce and understand spoken utterances. Peter's naming was intact. In fact, the areas of language that would normally be impaired in a person with aphasia were entirely normal. And yet he struggled to harness these linguistic resources adequately to tell an informative narrative or

to give a complete description of a picture. His informativeness in discourse production tasks fell not only well below the mean of healthy participants and Covid controls in the study but was also below the mean scores of male participants in both groups. The single exception was the Flowerpot Incident where Peter's score exceeded the mean score for Covid controls. Accordingly, it was not plausible to explain Peter's reduced informativeness in terms of a gendered narrative style. It was also not plausible to explain it in terms of limited education or a lack of experience in processing information, both of which could be excluded on account of Peter's professional role. The only feasible explanation appeared to be that Peter's Covid illness had impacted negatively on high-level cognitive-linguistic skills needed to construct informative discourse. This point warrants further consideration.

Peter's level of informativeness varied as a function of the cognitive demands of different discourse production tasks. He was most informative when the task provided visual input and a structure to his narration in the form of a sequence of pictures to follow. These were the conditions under which he narrated the Flowerpot Incident, a storytelling task in which he achieved 67% informativeness. As these cognitive supports were steadily withdrawn from Peter through changing task demands, his informativeness decreased markedly. When visual input was maintained but there was less external structure on his discourse production – the conditions in the Cookie Theft picture description task – Peter's informativeness dropped to 41%. When visual input *and* an external structure for Peter's discourse were removed – the conditions in the Cinderella story – Peter was least informative, achieving only 28% informativeness. Peter could not simultaneously generate a discourse structure for his storytelling and hold substantial information in memory about the characters and events in the Cinderella story. His processing capacity was exceeded at this point, resulting in a significant reduction in the informativeness of his spoken discourse.

That Peter appeared to struggle with competing demands on his cognitive resources was also suggested by his category fluency performance. Although he exceeded normative values for the generation of both animal and vegetable names, he produced eight category violations during his generation of vegetable names. This suggested that when Peter was under the dual

demands of generating names *and* monitoring the accuracy of his spoken output, one of these demands (monitoring) was subordinated to the other demand (generation), resulting in the production of category violation errors. Peter's Covid illness appeared to have lowered the cognitive threshold at which he could perform tasks with accuracy. Tasks with multiple, simultaneous demands that required flexible deployment of several cognitive skills now exceeded that threshold. Informativeness in discourse served as a linguistic marker of that flexible deployment and, in Peter's case, shone a light on an area of reduced cognitive capacity following his Covid infection.

Reduced informativeness is a well-recognized feature of discourse in adults with neurodegeneration,[1] even in the absence of dementia (Cummings, 2020a, 2020b). It has been documented in adults with Alzheimer's dementia (Cummings, 2019a; Pistono *et al.,* 2019), primary progressive aphasia (Cummings, 2019b), Parkinson's disease spectrum disorders (Ash *et al.,* 2017; Roberts and Post, 2018), and multiple sclerosis (Arnott *et al.,* 1997). Reduced informativeness in these populations has been related to linguistic impairments (particularly in progressive aphasia), cognitive deficits, and motor dysfunction. Adults who sustain traumatic brain injury (TBI) and right-hemisphere damage (RHD) have also been reported to exhibit reduced informativeness in discourse (Marini, 2012; Power *et al.,* 2020). Readers who are speech-language pathologists will recognise these populations as having cognitive-communication disorders. What Peter's case demonstrates is that these disorders are not limited to people with neurodegeneration and stroke-induced or trauma-related brain damage but that they can also arise in the presence of infectious disease. Peter's case is the first in which cognitive-communication disorder is described in a person with Covid-19 infection, albeit that his cognitive-communication difficulties are more subtle in nature than those typically reported in adults with neurodegenerative disorders, TBI and RHD. Given the large and mostly hidden burden of long Covid, it is certain that Peter's case will not be the last in which cognitive-communication impairments are identified.

NOTES

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[1] Covid-19 infection may also increase susceptibility to neurodegeneration; see Heneka *et al.* (2020) for discussion.

APPENDIX

Study group	Number	Age (mean)	Age (range)	Gender (M/F)	Education (years)
Covid participants[1]	35	47.1 years	24-64 years	4 M/ 31 F	9 under 17 years 26 over 17 years
Covid controls	6	44.3 years	31-58 years	3 M/ 3 F	1 under 17 years 5 over 17 years
Healthy participants	16	50.7 years	28-66 years	6 M/ 10 F	3 under 17 years 13 over 17 years
L2 English speakers[2]	5	41.0 years	36-47 years	2 M/ 3 F	5 over 17 years
TOTAL	62	47.3 years	24-66 years	15 M/ 47 F	13 under 17 years 49 over 17 years

[1] First languages of five Covid participants with L2 English: Chinese/Dutch; Romanian; Polish; Portuguese; and Italian
[2] First languages: Mandarin Chinese; Cantonese Chinese; French; and Spanish

Figure 1: Participant characteristics

Task	Peter	Healthy controls[‡] (N=16)	Covid controls[φ] (N=6)	Healthy males[φ] (N=6)	Covid males[φ] (N=3)
Sam and Fred (immediate recall)¶	60%	66% (42-92%)	67%	65%	67%
Sam and Fred (delayed recall)¶	42%	64% (39-85%)	61%	58%	61%
Cookie theft picture description¶	41%	66% (54-83%)	64%	62%	63%
Sentence generation	100%	87% (66-100%)	91%	83%	88%
Letter fluency (F-A-S)	49	46 (30-67)	50	43	52
Category fluency (animals)	26	25 (18-37)	21	24	21
Category fluency (vegetables)	17	16 (9-24)	17	12	18
Flowerpot incident narration¶	67%	73% (55-100%)	56%	70%	63%
Cinderella narration¶	28%	67% (47-90%)	64%	67%	63%
Procedural discourse (sandwich)¶	100%	90% (68-100%)	83%	92%	83%
Procedural discourse (letter)¶	100%	79% (25-100%)	89%	74%	100%
Confrontation naming	100%	88% (65-100%)	90%	88%	91%

[‡] Figures for healthy controls are means (range).

[φ] Figures are mean values.

¶ Figures indicate informativeness as percentage.

Figure 2: Peter's performance relative to healthy participants and Covid controls

Task	Peter[§]	Healthy participants Mean (standard deviation)	Comment
Sam and Fred (immediate recall)	8.5/14	9.4 (±1.9)	within 1 SD below mean
Sam and Fred (delayed recall)	6/14	9.0 (±1.9)	> 1 SD below mean
Cookie theft picture description	5/12	7.9 (±0.9)	> 3 SD below mean
Sentence generation	6/6	5.2 (±0.9)	within 1 SD above mean
Letter fluency (F-A-S)	49	46 (±10.1)	within 1 SD above mean
Category fluency (animals)	26	25.6 (±4.8)	within 1 SD above mean
Category fluency (vegetables)	17	15.9 (±4.2)	within 1 SD above mean
Flowerpot incident narration	13.5/20	14.75 (±2.3)	within 1 SD below mean
Cinderella narration	14/50	33.5 (±5.7)	> 3 SD below mean
Procedural discourse (sandwich)	8/8	6.7 (±1.0)	> 1 SD above mean
Procedural discourse (letter)	8/8	6.3 (±1.6)	> 1 SD above mean
Confrontation naming	20/20	17.6 (±2.1)	> 1 SD above mean

[§] Figures are raw scores

Figure 3: Peter's performance relative to healthy participants

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