Long Covid: A Longitudinal Perspective of Cognitive Impairment and Symptom Trajectories in a Working Age Sample.

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Thesis Abstract

SARS-CoV-2, has been shown to induce inflammation in the hippocampus which may lead to prolonged memory deficits in people with Long Covid (pwLC). While Long Covid (LC) is estimated to affect over 65 million people worldwide, its long-term cognitive and functional sequalae remain poorly understood.

Using a mixed-methods longitudinal design, this thesis investigated the symptom trajectories of LC. It also examined the lived experiences of pwLC, integrating qualitative insights alongside quantitative data.

People of working age (*N* = 68), most of whom (81%) had a formal LC diagnosis, completed sub-tests of the BIRT Memory and Information Processing Battery (BMIPB-II), a word categorisation and recognition task (Addante et al., 2012) and health surveys at three time points, from March 2023 to March 2025 with an average of 19 months between the first and third assessment (*SD* = 1.41) . Qualitative data from open-ended survey responses and semi-structured interviews, were examined using thematic analysis to capture lived experiences. Finally, a study protocol was designed to explore cortical dynamics of memory encoding and retrieval, to further delineate the neurophysiological underpinnings of the condition.

Persistent impairments in memory were observed for up to 60 months since LC diagnosis. Verbal learning and retention and speed of information processing were impaired on all assessments. Visual memory, semantic categorisation accuracy and speed were preserved. Participants self-reported up to 34 LC symptoms. The most frequent were fatigue, memory and concentration problems. PwLC demonstrated elevated fatigue compared to controls, which correlated with low quality of life.

Linear mixed modelling showed changes over time for some of the cognitive performance measures, but not on all other measures. Lived experience perspectives demonstrated the complex and multifaceted challenges of living with LC. The findings from this thesis evidence the persistent cognitive and functional deficits in pwLC, and may inform the development of better diagnosis and support pathways for pwLC.

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Firstly, I would like to express my sincere and biggest thanks to my supervisors. I am beyond grateful to have had your support during this roller coaster journey. I really do hope I am like you both when I am a grown up!

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Dedication

This work is dedicated to the entire Long Covid community. To the participants of this research without you this thesis would not have been possible and to those who have offered constant support and guidance throughout my studies, your contributions have been invaluable. To the millions still searching for answers, I see you. It has been a privilege to work closely with this community, and I remain in awe of your resilience, strength and courage. Please, never lose hope.

From testing my first participant, I had a spark ignited in me to try to make a difference to the LC community. I said to the first participant I spoke to in March of 2023, something along the lines of “I see you, I hear you and I am determined to make a difference" and this stuck with me throughout the highs and lows of my PhD journey. I was recently asked ‘has your research had any impact yet?’ and although I do not have any published articles, I know that my research and time has been invaluable to the LC community, so my answer was confidently ‘yes it has been impactful,’ which brings me the most pride. The small differences I have made to pwLC, and their gratitude, will stay with me forever.

This thesis has been a labour of love and I believe is a testament to the person I am. The curiosity and motivation to learn, the determination to work hard and overcome challenges, and the desire to understand and support others are values I hope are reflected in this work.

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Thesis Key Terms

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2): SARS-CoV-2 is a virus that causes the respiratory illness, Covid-19, which since its emergence in 2019 up until April 2025, is responsible for at least 7 million deaths worldwide.

Coronavirus Disease 2019 (Covid-19): Covid-19 is the respiratory illness caused bySARS-CoV-2.

Long Covid / PASC / PCC: Long Covid (LC), also known as Post- Acute Sequelae of SARS-CoV-2 (PASC) or Post Covid-19 Condition (PCC) are terms used to describe the symptoms that linger after an acute Covid-19 infection has passed. The abbreviation 'LC' will be used throughout this thesis to refer to the condition.

pwLC: This abbreviation stands for people with Long Covid.

Myalgic Encephalomyelitis / Chronic Fatigue Syndrome (ME / CFS): A post-viral condition characterised by persistent fatigue, cognitive dysfunction and other symptoms. The abbreviation 'ME / CFS' will be used throughout this thesis to refer to the condition.

pwME / CFS- This abbreviation stands for people with ME / CFS.

Chapter One: Introduction

This chapter introduces Long Covid, the illness in which this thesis is based upon, by providing background information, outlining common symptoms, prevalence and diagnosis. The chapter explores the neurological and psychological underpinnings of LC. Additionally, it contextualises existing research, identifies key gaps in the literature and highlights the need for further investigation. Finally, the chapter presents the thesis overview and outlines the specific questions the research seeks to address.

Background Information

March 2025 marked half a decade since the World Health Organisation (WHO) declared Covid-19 to be a pandemic (The World Health Organisation*,* n.d.). Covid19 is caused by the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV2), primarily a disease affecting the respiratory system (Miners et al., 2020), which quickly became a global pandemic since the first confirmed cases in Wuhan, China in December 2019 (Ravelo & Jerving, 2020). Covid-19 spread modality is airborne by respiratory droplets released into the air (e.g. via coughing) but it is also transmissible via the touching of surfaces, although this is less likely (Wang et al., 2021). As of April 2025, the global pandemic has seen 775,866,783 confirmed cases of Covid-19 worldwide (Mathieu et al, 2024). The identifiable symptoms of Covid-19 have changed and mutated over the duration of the pandemic due to the everchanging nature of the virus and its variants (NHS, 2023).

Coronavirus, like many other viruses, has continuous evolution causing mutation which leads to multiple variants of the original virus (Holmes & Rambaut, 2004). Variants of SARS-CoV-2 include Alpha, Beta, Gamma, Delta and Omicron (Esper et al., 2023). The presence of Covid-19 is confirmed using rapid lateral flow tests and / or polymerase chain reaction testing (PCR) by analysing swabs of samples taken from the nasal cavity and / or throat (NHS, 2025).

SARS-CoV-2, presents as heterogeneous in severity and symptoms (Owens et al., 2024). In asymptomatic cases, while individuals may not report any symptoms, they can contribute to asymptomatic transmission (Pollock & Lancaster, 2020). In cases of mild or moderate Covid-19, individuals normally recover from symptoms reducing or disappearing within one to two weeks of contracting the virus. A large portion of confirmed Covid-19 cases have been listed as ‘mild’ or ‘moderate’ with potentially worsening symptoms over time which can includes shortness of breath, among other symptoms (NHS, 2023). However, the severe form of acute Covid-19 can cause medical emergencies and has led to thousands of individuals being hospitalised, requiring ventilation and the death of Covid-19 patients (WHO, 2023). While the development of vaccines has reduced severe physiological symptoms and death caused by Covid-19 virus (Coccia, 2025), the long-term effects of Covid-19 remain an important medical concern. In October 2022, the Covid-19 virus was the eighth leading cause of death in the United Kingdom (Office for National Statistics, 2022).

Those who were clinically vulnerable including those with health concerns such as heart conditions, diabetes and a suppressed immune system, alongside the elderly

(65 years and above), were thought to be more at risk of serious illness when contracting Covid-19 (The Health Foundation, 2020). Recovery from acute Covid-19 appears to be dependent on the severity and length of time of symptoms. Three classifications of this syndrome have been identified; acute Covid-19 (lasting less than four weeks), ongoing symptomatic Covid-19 (lasting between four and 12 weeks) and Long Covid (lasting more than 12 weeks and where symptoms cannot be attributed to any other medical condition).

At the beginning of the coronavirus pandemic, therapies were understandably prioritising the exploration of the acute physical effects of Covid-19 upon the respiratory system due to the high death rates (Miners et al., 2020). However, in recent years, there has been an understanding that the impact of acute Covid-19 infection can be long lasting, can impact on cognitive functioning (Aretouli et al., 2025; Jaywant et al., 2024) and could lead to sustained neurological risk trajectory (Taquet et al., 2022) a prolonged impact and potential higher risk of neurodegenerative conditions such as Alzheimer’s disease and Parkinson’s disease (Baazaoui & Iqbal, 2022). LC is not only occurring in individuals who had a severe acute infection but is also evident in those who had mild infections (Davis et al., 2023; Greenhalgh et al., 2024).

Long Covid

Long Covid, a term initially coined by patients (Callard & Perego, 2021) during the first few months of the pandemic, is also known as Post- Acute Sequelae of SARSCoV-2 (PASC) or Post Covid-19 Condition (PCC). These terms are used to describe the constellation of symptoms that linger (more than 12 weeks) and continue after an acute Covid-19 infection has passed and described for individuals experiencing symptoms long after contracting the Covid-19 virus.

LC can affect people of any age or sex, however similarly to other chronic illnesses, the prevalence of LC seems to be higher in women and those between 45–54 years (Thompson et al., 2022) which corresponds to working age adults. The median age of natural menopause, around 51 years (Davis et al., 2023), overlaps with the age category of those at higher risk of LC. Many of the LC symptoms overlap with menopause symptoms such as decreased sexual desire, brain fog and difficulty concentrating (Davis et al., 2023), thus misdiagnosis may be a concern to women. Despite this overlap in symptoms, it is vital to understand its frequency and severity and their impact on everyday life. It is important that medical professionals differentiate between LC and the menopause and not assume that women of menopausal ages are not suffering with LC.

Impact on employment

Within the United Kingdom, there have been calls to the government for LC to be recognised as an occupational disease registered as a disability and to become a protected characteristic under the Equality Act, enabling financial support from the State's benefits for those unable to return to work (Starling, 2022). Several LC employment tribunals concluded that some symptoms have such a severe impact on daily life that the particular individual met the threshold for a disability (Starling, 2022). The Office for National Statistics reported that 78% of people with LC have found that the long-lasting effects of their symptoms forced their decision to either; stop, reduce or change their workload (The Office for National Statistics, n.d.).

As with any illness, reduced ability to work, adds financial pressures and additional stress to those who are unwell. As LC is a novel complex illness, consideration about supporting people with employment is required but currently there is limited evidence regarding impacts on the workplace (Izquierdo-Condoy et al., 2024). Research on the prevalence of LC symptoms reported that nearly half of the participants struggled to return to ‘normal’ life post Covid, including the requirement for a reduced work schedule due to their on-going symptoms (Lee et al., 2020). This, in turn, not only impacts the economy but also the wellbeing of the individuals affected. Long term illnesses, such as LC, have negative effects on both individual and their employers (Reuschke et al., 2024), with individuals often having few options available to them. The most frequent options are to permanently leave employment, attempting to negotiate symptom-dependent, reduced working hours or workplace adjustments or continuing to push through illness to remain economically active. A recent survey with a sample of 3,000 pwLC, demonstrated that 66% of participants felt they had received unfavourable treatment when at work (Kromydas et al., 2023). Furthermore, 23% declared they had conversations with their employers regarding the severity of their symptoms in order to confirm their experience (Kromydas et al., 2023).

In the United Kingdom, the standard statutory sick pay (SSP) system supports employees for up to 28 weeks; however, pwLC may require more time off work than this depending on the long-lasting nature of symptoms. One study has shown median time off work sick attributed to Long Covid was 60 days (Ziauddeen et al., 2022). The weekly SSP rate is £116.75 as of April 2025 (GOV, 2025) which, for individuals accustomed to earning full or part-time wages this may not adequately compensate. Thirty seven percent of participants in one study reported loss of income due to Covid-19 related sickness absence (Ziauddeen et al., 2022). Some employers offer occupational sick pay; however, this is usually time-limited, which coupled with the non-linear recovery of LC may add financial strain to pwLC.

A study by Reuschke and colleagues (2024) was the first to examine work outcomes for pwLC in a large sample (*N* = 19,763). Participants were split between two groups. The first group (*N* = 9,288) had LC for between five and twenty-eight weeks after their initial Covid-19 infection and the second group (*N* = 8,708) had symptoms lasting 29 weeks or longer . The authors discovered that for those who remained in work, there was an impact to their employment due to sickness leave. Furthermore, for those who had had symptoms lasting longer than 29 weeks, there were negative effects on their general mental health and wellbeing. This highlights that many individuals may return to work primarily due to economic pressures rather than full recovery.

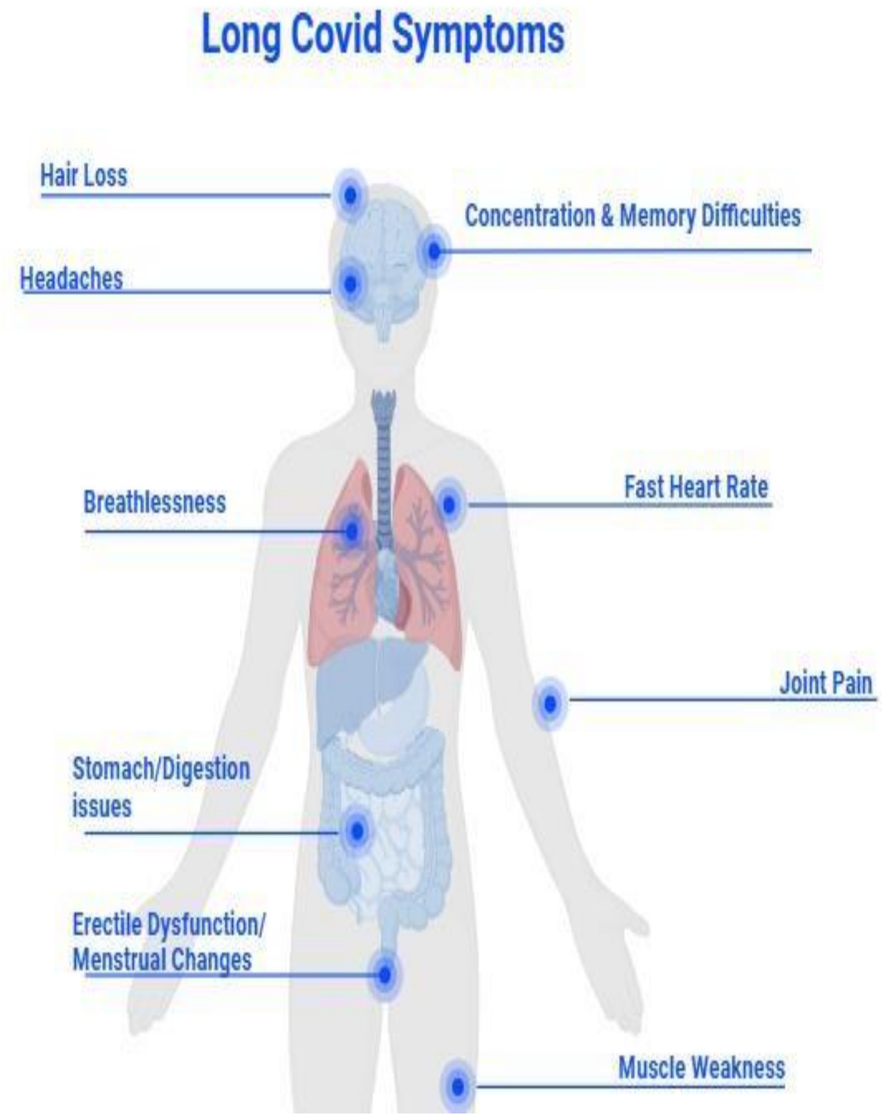
One study aimed to explore ongoing LC symptoms in regard to the pattern and progression to explore the impact on daily activities and work (Ziauddeen et al., 2022). The study included 2550 participants (*N* = 675 confirmed infections via PCR test) who had been living with LC for an average of seven months, with mean age 46.5 years and 82% being female. Nine percent of participants reported reduced working hours and 19% were unable to work (of which 88% attributed this solely to Covid-19). There were limitations noted with this study including participants being recruited online, only a proportion of participants had confirmed acute Covid-19 infection and the sample was predominately female.

A systematic review and meta-analysis conducted by Ottiger and colleagues in 2024, explored studies on work abilities and work-related outcomes for people living with LC. This review examined over 20,000 patients' across 14 countries and found that LC symptoms, including fatigue, impacted patients ability to work. Around 60% were able to return to work typically 12 weeks post infection, but highlighted that workplace support and occupational rehabilitation programmes were vital in supporting this return to work (Ottiger et al., 2024)

While cases of acute Covid-19 continue to spread, with new variants being detected in June 2025 (Finighan, 2025), the risk of LC reducing capacity to work remains and is likely to continue to be a problem moving forwards. Therefore, research into the long-term effects of LC in the working age population and how this may impact upon employment is vital.

LC prevalence ranges between 26 - 41% among infected Covid-19 adults (Nittas et al., 2022) and there are no significant differences between different Covid-19 variants and developing LC (Du et al., 2022). There are over 200 documented symptoms of LC, affecting many organs within the body. These symptoms range from mild to severe and can fluctuate over time. Commonly reported symptoms are illustrated in Figure 1.

Figure 1. Common LC symptoms



LC symptoms vary widely among individuals, with some experiencing predominantly physical impairments, such as respiratory issues, chronic pain, or cardiovascular complications, while others suffer more from cognitive difficulties, including memory deficits, concentration and information processing difficulties (Hampshire et al, 2021)

Research has suggested that there are three main LC symptom / cluster types (Guo et al., 2022). The first is neurological, with the most reported symptoms including brain fog, anosmia, headaches, delirium and fatigue. The second is respiratory, due to possible damage to the lungs, and includes chest pains, shortness of breath and severe fatigue when mobile. The third cluster type is suggested to be systemic / inflammatory and includes musculoskeletal pain, anaemia and gastrointestinal issues (Guo et al., 2022).

Among the most commonly reported and debilitating symptom is fatigue, affecting a significant proportion of those with LC (Calabria, 2022; Ceban et al., 2022). Fatigue in pwLC is often described as profound, exacerbated by even minor physical or mental exertion, a phenomenon known as post-exertional malaise (PEM). Post exertional malaise (PEM), worsening of symptoms following any physical or cognitive exertion (Dehlia & Guthridge, 2024) is one of the most common and often debilitating symptoms of ME / CFS that have also been reported by pwLC (Dehlia & Guthridge, 2024).

Walker and colleagues (2023) explored the impact of fatigue on those with LC in a large study with nearly 4000 participants of working age (*M* = 48 years) across England and Wales. Participants completed self-reported measures of fatigue, quality of life and functional impairments as well as surveys assessing cognitive symptoms. The authors discovered high levels of functional impairment and found fatigue to be the main symptom. Furthermore, the participants had low scores on a measure of quality of life (QoL) and over 75% of participants had moderate to severe cognitive deficits as self-reported on surveys (no effect sizes reported). Cognitive impairment, often referred to as "brain fog" in LC patients, can also severely impact on daily functioning, making tasks such as reading, working or even holding conversations challenging. These findings provide evidence of the significant burden of LC but the study did have some limitations including self-reported data which may reflect some response and recall bias.

For many pwLC, symptoms from different systems coexist (Long Covid Support,2025), further complicating diagnosis and treatment. Evidence suggests that LC having profound impact on daily functioning, quality of life, mental health and employment abilities (Poletti et al., 2022). Although much attention has been given to the physical symptoms of LC, cognitive dysfunction remains one of the most debilitating and persistent symptoms reported by pwLC (Ceban et al., 2022; Hampshire et al., 2024). There is evidence that Covid-19 has the capacity to cause more wide-spread damage within the body than originally thought, including to organs such as the brain which in turn has the potential to impact upon cognitive functioning (Miners et al., 2020). It is believed that more than four million people worldwide are suffering with LC (Al-Aly et al., 2024).

Cognitive Symptoms

One of the most commonly reported symptoms in pwLC is ‘brain fog’, a non-medical term that is used to refer to general cognitive dysfunction including on word finding difficulties, memory impairments and attention amongst other symptoms. These cognitive difficulties can significantly affect the quality of life for pwLC, impacting their ability to work, engage in social activities and perform routine tasks. Brain fog has been linked to increased difficulties in daily functioning of pwLC, with numerous studies confirming the negative impact on cognitive functioning (di Filippo et al., 2023; Jennings et al., 2022; Premraj et al., 2022).

There is variation in the cognitive concerns reported by pwLC, which can range from short term memory impairments (Hampshire et al., 2024) to reduced attention and focus (Herrera et al., 2023). These cognitive concerns have been evidenced by poorer performance in cognitive tasks, and its severity has been linked to factors such as the length of time since the acute infection and the need for hospitalisation (Guo et al., 2022; Hampshire et al., 2024; Jennings et al., 2022). These factors appear to exacerbate the cognitive deficits observed in pwLC, with prolonged symptoms often correlating with more significant impairments in cognitive functioning.

Memory and learning are among the primary cognitive concerns for pwLC, who have reported difficulties with both short-term and long-term memory, as well as problems with concerns that involve working memory, attention, concentration and reduced processing speed. Additionally, executive function deficits, which affect planning, decision-making, and problem-solving, are also commonly observed (Guo et al., 2022). These impairments may have consequences on activities of daily living (Vaughan & Giovanello, 2010).

Diagnosis and Treatment

The formal diagnosis of LC, similar to other post-viral illnesses, is based on clinical assessments rather than one definitive test (Grebe & Singh, 2011). A diagnosis is based on exclusion, eliminating all other possibilities, rendering it the most likely explanation of the symptoms. Given the diverse, fluctuating, and often unpredictable nature of symptoms, diagnosis relies on a combination of patient history, and medical examination of the symptom presentation, to allow exclusion of other conditions that could explain persistent symptoms following a SARS-CoV-2 infection (O'Hare et al., 2022).

The World Health Organization (WHO) provided an official definition of LC in October 2021, describing it as a condition that occurs in individuals with a history of confirmed or probable Covid-19 infection and involves symptoms lasting at least 12 weeks, which cannot be explained by an alternative diagnosis (The World Health Organization, 2025). The WHO also recognise that LC affects multiple organ systems and symptoms can fluctuate or relapse over time. Similarly, the National Institute for Health and Care Excellence (NICE) in the United Kingdom defines LC as symptoms persisting for more than 12 weeks after initial infection, distinguishing it from ongoing symptomatic Covid-19, which refers to symptoms lasting between four and twelve weeks (NICE, 2020). A formal LC diagnosis typically involves gathering of medical history from the individual including details of symptoms onset, duration, and progression, confirmed or suspected Covid-19 infection and exploration of preexisting health conditions and risk factors. Assessments are completed of the most common symptoms, including fatigue, cognitive dysfunction, breathlessness, chest pain, autonomic dysfunction, and musculoskeletal pain. Validated tools such as the Covid-19 Yorkshire Rehabilitation Scale (C19-YRS; Sivan et al., 2020) are used to measure symptom severity and impact on daily life. The C19-YRS is a clinical and patient reported outcome measure to capture symptom burden, functional disability, the impact on daily activities and overall health. The scale has high internal consistency (Cronbach's $\alpha = 0.891$) (O'Connor et al., 2022) supporting its use as a reliable measure of LC symptom severity and functional impact. The process of diagnosis for LC as stipulated by WHO and NICE is also to exclude other conditions that the symptoms could be attributed to. These exclusion tests usually include blood tests, imaging, cardiac assessments for individuals with palpitations or chest pain and autonomic testing for suspected dysautonomia such as postural orthostatic tachycardia syndrome (POTS).

During and after diagnosis, patients may be referred to multidisciplinary teams including neurology, cardiology, or rehabilitation depending on their symptom presentation (Nurek et al., 2021). A multidisciplinary approach can often also include referrals to occupational therapists, physiotherapists, and psychologists to support symptom management (Schultz et al., 2024). Due to fluctuating symptoms and the requirement of a multidisciplinary approach, there can be challenges in diagnosing LC. To date, there is no definitive biomarker to diagnose LC, Symptoms can be similar to other conditions which also adds to diagnostic challenges. Unfortunately, despite Covid-19 being around since 2020, there is still limited awareness among healthcare providers which has resulted in patients struggling to obtain recognition and support due to inconsistent guidelines and reporting ‘medical gaslighting’.

‘Gaslighting’, a term previously associated with relationships and workplace environments, refers to denial, dismissal and manipulation (Khan et al., 2024). However, in recent years the term ‘medical gaslighting’ has been used within healthcare (Ng et al., 2024). Medical gaslighting for pwLC includes downplaying the reality of the illness, delayed diagnosis and therefore treatment and negative experiences with health care professionals (Au et al., 2022). Medical gaslighting has been a concern for the LC community (Au et al., 2022; Mariani, 2022). Interviews conducted with pwLC reported dismissal and lack of concern with wellbeing by healthcare professionals (Spence et al., 2023) in a qualitative study. This has led to many pwLC feeling frustrated, alone and anxious, and searching for support in online communities to feel validated and reduce the risk of repeated gaslighting. A formal diagnosis is crucial for patients to be able to access treatment and rehabilitation services and can help support employment and access disability adjustments for individuals experiencing persistent symptoms (Schultz et al., 2024).

From July 2021, research and knowledge into the potential of long-lasting effects and symptoms of acute Covid-19 began to expand. This effort was supported in the United Kingdom with 120 million pounds of funding by the National Institute for Health Research (NIHR, 2021) and led to the World Health Organisation establishing a formal definition of LC in October of the same year as previously mentioned. Fortunately for pwLC, this offered some validation that LC is a health condition. Prior to October 2021, there was a lack of clinical guidance for those supporting patients with LC, meaning that for more than one year since the outbreak of the global pandemic medical professionals struggled to diagnose and treat severe lingering symptoms associated with it.

During the early days of the pandemic, particularly prior to the WHO LC definition, there was a lack of treatment options, coupled with high demand due to improving survival rates. This made implementing and accessing efficient and effective rehabilitation difficult (Verduzco-Gutierrez et al., 2021). Research discussed the need for efficient cognitive rehabilitation post Covid-19 (De Biase et al., 2020) but the research focused solely on rehabilitation for the elderly (> 65 years), which may not be generalisable to all Covid-19 survivors, including those of working age. However, the authors did suggest that key areas for future research included exploring the impact of type and severity of deficits (e.g., cognitive and physical) attributed to Covid-19 and the long-term impact of these deficits (De Biase et al., 2020) including ability to work and quality of life.

When the need for support and rehabilitation with post Covid-19 syndrome was recognised within the UK, LC clinics were founded across the country with the aim of supporting individuals with the long-lasting effects of post Covid-19 syndrome (NHS, n.d.). Assess and rehabilitating these needs became recognised as imperative, particularly those arising from any neurological impact, with these services being made accessible to anyone who required them (Verduzco-Gutierrez et al., 2021). LC clinics focused on equipping pwLC with the skills to manage their symptoms, thus minimising the impact on their daily functioning. Unfortunately, as of January 2025, the funding for LC clinics has been reduced and clinics have been closed across the UK (Long Covid Support, 2025), despite the high demand for these services, which is a cause of concern moving forwards.

Symptom management

The management and rehabilitation for LC varies greatly dependent on the severity of the symptoms. The management of physical symptoms may include the use of pharmaceutical pain relief and rest, but each individual should receive a personalised support plan specific to their needs (Nabavi, 2020). For example, persistent sense of smell loss may have frontal lobe damage (Reiss et al., 2023) and require different rehabilitation from difficulties affecting executive functions. The metaphor ‘boatman’s plight’ encourages patients to prioritise what to keep or discard in their rehabilitation, (Weingarten, 2013) may be applicable to pwLC suffering from multiple symptoms. In November 2022, the first LC support app, ‘Visible’ was launched to help monitor LC symptoms (Visible*,* n.d.). It specifically measures physiological data in the hope that this can provide some support to users and further our understanding of the physiology of LC both for individuals and for the general LC population.

The National Institute for Health and Care Excellence (NICE), alongside the National Health Service (NHS) have developed a framework and guidance for clinicians in primary care settings. Multidisciplinary approaches have been found to lead to the best outcomes and ensure that all symptoms and presentations of LC are being managed. Rehabilitation programmes can be helpful, but these should be implemented with caution, and prescribed by specialist teams including professionals such as occupational therapists and physiotherapists, as Physical exercise should be carefully managed because there is evidence to demonstrate that, in some cases, it has made symptoms and the trajectory of LC worst (Greenhalgh et al., 2024).

In sum, LC is a complex illness that affects individuals of all ages and who have experienced acute Covid-19 infection of various degrees of severity, including those who had mild or asymptomatic initial infections. Symptoms can vary widely and may affect multiple organ systems (Long Covid Support, 2025). While the exact causes remain unclear, potential contributing factors include brain inflammation, immune system dysregulation, and autonomic dysfunction, as discussed in this thesis. These contribute to cognitive symptoms such as memory problems, attention deficits, and brain fog, leading to challenges in daily functioning and ability to work. It is now more than five years since the pandemic began but despite ongoing research, there is still no single treatment for LC. However, understanding cognitive deficits, such as memory deficits, may lead to targeted rehabilitation strategies.

Neurological and Psychological Underpinnings

The neurological and psychological effects of LC have been widely documented, with emerging evidence suggesting significant alterations in both brain function and mental health. These changes can be attributed to various mechanisms, including the direct impact of the virus on the nervous system, as well as secondary psychological responses to chronic illness.

Brain Inflammation and Immune Response

Studies have indicated that individuals with LC exhibit elevated markers of neuroinflammation, which may contribute to cognitive deficits like memory problems and concentration difficulties (Ceban et al., 2022; Guo et al., 2022). Neuroinflammation can lead to synaptic dysfunction and neuronal damage, especially in regions of the brain involved in memory and attention, such as the hippocampus and prefrontal cortex (Hampshire et al., 2024).

While post-viral conditions are not new, due to the novelty of the Covid-19 virus, the causes of LC are still being explored. The underlying mechanisms of LC are suggested to involve a combination of factors including, virus persistence where there is evidence to suggest that the SARS-CoV-2 virus produces its own proteins into various cells within the body including the cardiovascular system and gastrointestinal systems, these proteins can trigger autoimmunity from the infection (Skevaki & Wesemann, 2023). Reactivation of dormant viruses such as herpesviruses and Epstein-Barr virus and/or inflammation in one organ can cause alterations in various other tissues and organs, including prolonged changes in the body’s central nervous system and changes to the blood and cortisol levels. Inflammation in the brain, specifically in the hippocampus region has been attributed to neurological issues in those with LC (Greene et al., 2024). The hippocampus is located in the medial temporal lobe of the brain and is part of the limbic system and can be damaged by inflammatory responses, lack of oxygen, direct infection, blood clots and neurodegenerative diseases.

A recent study used susceptibility weighted imaging, a type of magnetic resonance imaging (MRI), to explore significant brain changes in pwLC (Mishra et al., 2023). The authors aimed to explain cognitive issues and anxiety in those with LC. This type of imaging is frequently used to detect neurological disorders such as that caused by acquired brain injuries (ABI) such as strokes. The authors found changes in both the brain stem and frontal lobes, which were linked with anxiety, fatigue and cognitive impairments in this study. This research highlights the structural effects the SARS-COV-2 virus is having on the brain, and hypothesises a physiological explanation for the observed functional cognitive impairments.

A more recent neuroimaging review explored the effects of LC on brain structures and function (Guedj et al., 2025). Positron emission tomography(PET) imaging revealed reduced cerebral glucose metabolism in numerous brain regions including the limbic areas, olfactory regions and cerebellum. This hypometabolism suggested altered neural function and may provide supporting evidence for the persistent cognitive difficulties reported by pwLC. This study provides neurobiological evidence of brain alterations in pwLC.

Furthermore, Covid-19 virus itself has been detected in LC patients' brain tissue post-mortem (Malik et al., 2021). Small lesions in the brain tissue have been reported for Covid-19 patients, which may have been caused directly and indirectly by the inflammatory response of the body to the Covid-19 virus. Correspondingly, changes have been detected post-mortem within both grey and white brain tissue matter. White tissue matter which comprises 60% of the brain’s tissue, resides deep within the subcortical areas of the brain and contains axons, extensions of neurons which also send signals to the spinal cord and CNS. White brain matter is important for transmitting sensory information; therefore, its integrity is important for maintaining cognitive function (Bennett & Madden, 2014). Grey matter makes up the other 40% of the brain’s tissue and consists of neuronal cell bodies and axon terminals, which form synaptic connections with other cells. Disruption in these tissues may impair cognitive performance, which is supported by research by Guo and colleagues (2022). The authors raised the possibility that excess immune response to the Covid-19 virus, may lead to the disruption of neurological function that can cause cognitive consequences to linger.

Early loss of synapse, which are responsible for cell communication throughout the body and brain, are attributed to neurodegenerative disorders including dementia and Lewy body dementia, and share co-morbidities with Acquired Brain Injury. These includes memory deficits and changes behavioural control. Viral invasion of the CNS is also linked with early synapse loss (Henstridge et al., 2019). Abnormal blood clotting, a form of ischaemic damage, has been found in patients with LC, which could have resulted in their neurological damage and cognitive impairment (Guo et al., 2022). Furthermore, significant ischaemic damage has been discovered postmortem in Covid patients, strengthening the evidence of a possible link between CNS, Covid-19, neurodegenerative diseases and cognitive deficits (Miners et al., 2020a). For some pwLC, hypoxia, reduced oxygen levels, or microvascular damage could be underlying causes of cognitive dysfunction. Covid-19 can lead to reduced oxygen supply to brain tissue, potentially contributing to memory impairments, reduced processing speed, and difficulty with complex tasks (Ceban et al., 2022). The virus has also been found to induce blood clotting and microvascular changes, which may impair cerebral blood flow and exacerbate cognitive deficits (Premraj et al., 2022).

Autonomic Nervous System

The autonomic nervous system (ANS) controls involuntary physiological functions like heart rate, blood pressure, digestion, and respiratory rate (Waxenbaum et al., 2025). The ANS is divided into three main components. Firstly, the Sympathetic Nervous System (SNS) prepares the body for fight or flight responses during stress or emergencies. It increases heart rate, dilates the pupils, and redirects blood flow to muscles, among other responses. Secondly, the parasympathetic nervous system (PNS) is responsible for digestion functions, helping to conserve energy and promote relaxation. It slows down the heart rate, stimulates digestion, and helps maintain a state of calm when the body is not under stress. Thirdly the enteric nervous system (ENS) controls the functions of the gastrointestinal system, including digestion and absorption. While it operates independently from the PNS and SNS, it is influenced by both the sympathetic and parasympathetic systems. The ANS can be dysregulated in pwLC, often presenting as postural orthostatic tachycardia syndrome (POTS) (Fedorowski & Sutton, 2023), which is commonly reported in pwLC and can contribute to symptoms like dizziness, fatigue, and cognitive dysfunction (Verduzco

Gutierrez et al., 2021). These symptoms may further affect the ability to focus and process information efficiently.

Psychological Effects

In addition to the neuropsychological symptoms described, LC also has psychological effects, largely driven by the stress and uncertainty of living with a chronic illness (Higgins et al., 2021). The mental health burden of LC is substantial and includes both direct psychological impacts of the viral infection and secondary effects related to lifestyle changes (Cénat et al., 2021)

The physically debilitating nature of the illness is reported to have a significant effect on people’s quality of life and general wellbeing and affects the ability to work (Guo et al., 2022), which in turn could lead to anxiety and depression. Anxiety and depression are common in pwLC, who report increased mental health difficulties following their infection. The psychological burden may be related to prolonged illness, physical limitations and also uncertainty about the illness. In a systematic review (Cénat et al., 2021), it was identified that those with LC suffer beyond the initial medical symptoms. The results described symptoms of depression (15%), anxiety (15%), Post Traumatic Stress Disorder (PTSD; 22%) and psychological distress (13%) in pwLC. Similar prevalence of depression has been observed with SARS and MERS (Butler et al., 2020) and in a Canadian study on SARS, where 17% of participants were still not able to return to work one year later (Tansey et al., 2007).

PwLC may experience symptoms of post-traumatic stress disorder (PTSD), particularly those who faced severe illness or hospitalisation during the acute phase of the infection (Ismael et al., 2021). Symptoms of PTSD can include flashbacks, nightmares, and severe anxiety, which may interfere with cognitive functioning and overall well-being (Cénat et al., 2021).

Furthermore, the stigma surrounding LC and the difficulties in obtaining recognition for the condition may also negatively affect mental health. A social media-based study examined the lived experiences of pwLC, highlighting the stigma associated with the condition (Pantelic et al., 2022). The findings revealed that ninety-five percent of the participants reported stigma related to their diagnosis, with 86% specifically stating internalised stigma with diminished sense of self-worth, embarrassment and feelings of shame. Additionally, 91% of participants expressed fear of prejudice including concerns about employment security and potential discrimination, while 63% reported direct experiences of discrimination, ranging from social exclusion to loved ones reducing contact due to their illness. The findings from this study mirror stigma-related challenges observed in other conditions such as human immunodeficiency virus infection (HIV) and the acquired immunodeficiency syndrome (AIDS), which highlights misconceptions regarding acute infections/viruses. Research has identified mental health consequences as a significant concern for pwLC, further underscoring the importance of addressing both the psychological and social impacts of the condition (Cénat et al., 2021).

The delay of LC being formally defined may have contributed towards stigma as people reporting that their LC concerns went unheard and LC has been referred to as an invisible illness (Volpe & Diamond, 2021). In the introduction to the book ‘Breaking free from Long Covid’, Gahan(2022) highlights the feeling of being unheard, dedicating her work to “….every person each day with invisible illness and to those who believe us” (pg. 5, 2022). This dedication reflects the struggles of those with LC, many of whom face challenges in having their condition recognised. Gahan (2022) shares her own experience of becoming her own advocate, as her LC symptoms initially went unrecognized by the medical profession, which lacked the resources to assess those whose lives were not in immediate danger. She was often turned away by healthcare services, which led to feelings of being misunderstood and anger toward others’ dismissive responses to LC.

Fortunately, over the last four years, research and medical professionals have begun to acquire the requisite information to help aid the understanding of LC; however, this is not uniform. Alongside medical gaslighting, there are reports of gender stereotypes, typically prejudice towards women’s health (Lloyd et al*.,* 2020), whereby women were seen as more emotional and thought to be exaggerating their symptoms. This in turn restricted their access to appropriate and suitable medical care. Women have reported to feel dismissed by male medical professionals (Barker, 2005) and also often made to feel that they were unreliable at reporting their own health concerns. Unfortunately, this invalidation continues to exist and contributes to delayed care across in a variety of chronic conditions including women with polycystic ovary syndrome (Soucie et al.,2021), Lyme disease (Dumes, 2020) and LC (Au et al., 2022; Spence et al., 2023).

Comparison of LC to Post-Viral Illnesses

Despite SARS-CoV-2 causing a global pandemic, this is not a novel virus to have long lasting effects. Between 2002 and 2004, the severe acute respiratory syndrome (SARS) caused over 800 deaths worldwide (Patcai, 2022) and long-term complications for survivors were reported which included fatigue, cognitive impairments and changes to mood several years post infection (Mak et al., 2009). Forty percent of SARS survivors reported chronic fatigue and just under 27% of those met the criteria for CFS (Lam et al., 2009). In 2012, similar long-lasting effects were also seen with the middle east respiratory syndrome (MERS) outbreak, offering evidence that viral conditions can trigger long lasting effects (Azhar et al., 2019). MERS patients also demonstrated chronic fatigue at both 12 and 18-months postinfection (Lee et al., 2019).

LC shares many characteristics with other debilitating post-viral syndromes, particularly ME / CFS (National Academies of Sciences et al., 2024) that can be triggered following an acute infection (Vernon et al., 2025), and post-viral fatigue syndromes (PVFS) that have been documented following infections such as Epstein Barr virus (EBV). Epstein-Barr virus (EBV) has been linked to long-lasting neurological and cognitive effects similar to those experienced by individuals with LC (Soldan & Lieberman, 2020). Given the similarities between LC and other post viral conditions, it is possible that LC is causing a prolonged immune response disrupting the brain functions. Symptoms such as brain fog, autonomic nervous system dysregulation and energy regulation are seen across viral infections (Foster, 2024).

There are many symptoms that overlap between LC and ME / CFS, some of which are displayed in Table 1 (Dehlia & Guthridge, 2024; Wong & Weitzer, 2021).

Table 1. Symptom overlap between LC and ME / CFS symptoms

Symptom	**ME / CFS**	**LC**
Fatigue	✓	✓
Post-exertional malaise (PEM)	✓	✓
Headaches	✓	✓
Sleep issues	✓	✓
Impaired memory	✓	✓
Impaired attention	✓	✓
Depression	✓	✓
Anxiety	✓	✓
Reduced activity	✓	✓
Muscle weakness	✓	✓

A meta-analysis that was conducted to delineate cognition complaints often associated in pwME, reported difficulties with episodic verbal memory including storage, retrieval and recognition, as well as difficulties with attention (Sebaiti et al., 2022). The review supports the view of the heterogeneity of cognitive profiles in ME / CFS, where some domains are more affected than others. Neuroimaging has also supported this by evidencing structural brain changes including reduced grey and white matter (Puri et al., 2012) alongside, altered brain function during cognitive tasks (Cook et al., 2007). A recent meta-analysis examined the overlap between LC and ME / CFS patients (Dehlia & Guthridge, 2024) and found that 51% of a total of 1,973 individuals met the criteria for a ME / CFS diagnosis. This result is not surprising given the ME /CFS criteria emphasises certain symptomology including post- exertional malaise and persistent figure, symptoms that are frequently expressed by pwLC. This meta-analysis provides support that a subset of pwLC may represent a post-vial fatigue phenotype consistent with ME/ CFS. However, there were some limitations to the meta-analysis including heterogeneity across studies including the diagnostic criteria used to diagnosis ME / CFS, self- reported symptoms measures rather than confirmed diagnoses and variability in time since acute Covid-infection. Regardless of the limitations, this meta-analysis has important implications for clinicians for assessments and interpretation of LC symptoms.

A recent study, DeCodeME (2025), discovered genetic differences in nearly 16,000 individuals with ME / CFS compared to 259,000 healthy controls. The study identified eight significant genetic differences, three of which were linked to the body's immune response to viral or bacterial infection. Interestingly, four of the eight differences were associated with PEM and Fatigue. As DNA changes minimally over time, these findings provide evidence that ME / CFS has biological underpinnings rooted in immune and genetic vulnerabilities and that infection can lead to long lasting chronic illness. This discovery has direct relevance for LC, as both conditions often follow acute viral infection and share several symptoms as shown in Table 1. The identification of CA10 which proposed role is synaptic transmission and linked to chronic pain (*DeCodeME*, 2025) offers evidence for the possible mechanisms underlying the pain that is often described by pwME / CFS and which may help to reduce the stigma of the condition. Stigma refers to a label that can be placed on individuals and groups and is often of a negative connation. Individuals with ME often suffer with ongoing uncertainty and ambiguity around their illness, alongside stigma (Fennell et al, 2021). To this end, the eight genetic signals did not show links with depression or anxiety which refutes the claim that pwME/CFS often face, of a psychosomatic basis for their symptoms.

Furthermore, the study identified genetic variants associated with ME / CFS that may alter the gene expression in the hippocampus, which is key for memory. This may suggest evidence for the cognitive symptoms in pwME / CFS, which may have relevance for pwLC. There was strong evidence to suggest an increase of SUDS3 and DARS2 and a decrease in RABGAP1L in the hippocampus. The various functions of these specific genes include cell stress responses and neuronal function (Aradjanski et al., 2017), which may affect hippocampal integrity. These differences may contribute to encoding memories, spatial disorientation and a disturbed sense of self, symptoms reported by both pwME / CFS and pwLC. These findings suggest that, like ME / CFS, LC may trigger underlying immunological and neurological processes, that lead to persistent immune dysregulation and impairments of the hippocampus.

A smaller-scale study mapped genetics in pwLC (Chakraborty et al., 2024), providing evidence of neurological and inflammatory mechanisms. The specific genes they discovered in pwLC may help to explain the cognitive impairments of pwLC. Platelet Factor 4 (PF4) which is involved with clot formation and platelet activation (Kowalska et al., 2010) may contribute to impaired cerebral blood flow and therefore result in cognitive symptoms such as brain fog and fatigue, symptoms that are commonly reported by pwLC. The effects of these genes can impact on the hippocampus and surrounding cortices, and may provide a biological basis for the memory deficits observed in pwLC.

The findings from the review, not only demonstrate the symptom overlap between LC and ME / CFS but also suggests that LC can trigger ME / CFS in a proportion of patients (Dehlia & Guthridge, 2024). Given this, it is important to consider the lessons learnt from ME / CFS patients and research, which may inform LC research.

While there is research evidencing cognitive deficits in pwME / CFS, this is conflicting. As examples, deficits in episodic verbal memory have been reported (Sebaiti et al., 2022), alongside speed of information processing deficits reported (DeLuca et al., 1995) but other studies have found contradictory results with regards to memory (Michiels et al., 1998), and speed of processing (Short et al., 2002). This may suggest individual variability in cognitive performance. However, methodological limitations may also offer explanations to contradictory research findings within ME / CFS research.

A meta-analysis (Cockshell & Mathias, 2010) attributes inconsistent findings across cognitive domains in pwME / CFS to lack of control groups, use normative data that were not matched for age and education, variance in published diagnosis criteria and small sample sizes. This highlights the importance of careful consideration of these factors in LC research to ensure consistent, reliable results. The differences observed in findings on ME / CFS research, should also be anticipated in research with pwLC, due to the variable and fluctuation of symptoms of LC (Long Covid Support, 2025). Stratifying participants based, not only on the presence of LC, but different factors which may account for variance in performance such as fatigue and severity, could help to ensure that any cognitive deficits uncovered are associated to LC rather than attributed to uncontrolled heterogeneity within participant samples.

There have been differing ME / CFS definitions used over time such as the chronic fatigue syndrome definition (Fukuda et al., 1994) and the Candain Consensus Criteria (Carruthers et al., 2011). Unfortunately, variance between definitions has contributed to delayed, missed or unreliable diagnosis (Jason & Sunnquist, 2018), alongside limited healthcare specialist knowledge (Nacul et al., 2021). The lack of clinical diagnosis for some pwME / CFS has contributed to health needs being unmet for a large proportion of individuals (Nacul et al., 2021). Fortunately, this is not the case for LC, as the WHO has defined LC; however, the symptom overlap with other conditions could complicate research. Ensuring formal diagnosis of LC participants, supported by the WHO criteria, would increase reliability of LC research findings and reduce the risk of attributing any deficits to other conditions. However, Hampshire and colleagues (2024) did find cognitive deficits in patients with and without a formal diagnosis, which suggests that while diagnosis is important, symptomatology can still capture impairments where formal diagnosis is missing.

PwME / CFS have faced uncertainty and stigma around their condition (Fennell et al., 2021), as well as an impact on sense of identity (Larun & Malterud, 2007). Patients have reported feeling challenged about the legitimacy of their condition, increased vulnerability with medical professionals and frustration at the lack of understanding from others (Larun & Malterud, 2007). These qualitative findings also hold importance for pwLC. They provide insight into a patients’ perspective, how validation is critical, and points to how this may help to alleviate stigma and frustration experienced by this population. Ensuring the voices of pwLC are heard within self-reported surveys and qualitative data collection, may improve not only validation for the participants, but also contribute towards reduced stigma for pwLC.

Comparisons of LC and Other Patient Groups

Alarmingly, the cognitive dysfunctions reported in pwLC are similar to the deficits observed in neurodegenerative conditions such as Alzheimer's Disease (Baudic et al., 2006) and in those with hippocampal damage (Cave & Squire, 1992; Hannula et al., 2007). This raises the question whether LC may be characterised by similar structural and functional neurophysiological changes. Research has repeatedly suggested that the prolonged neuroinflammatory response in those with persistent symptoms may cause or accelerate existing neurodegenerative damage like that in Alzheimer's Disease (e.g., Elizalde-Díaz et al., 2022; Fu et al., 2022; Zhao et al., 2024). There is evidence that the SARS-CoV-2 virus targets the central nervous system (CNS) to activate an immune response (Barrantes, 2020). Inflammation of the CNS has been linked to the prolonged exposure to the virus, with up to nine thousand patients (0.22%) out of 4 million Covid-19 cases, affected by CNS complications (Ellul et al., 2020). For example, Covid-19 patients have shown reduced synaptic quantity and density (Oxley et al., 2020; Wang et al., 2020), comparable to patients with dementia (Henstridge et al., 2019a). Such brain structural and functional changes are likely to contribute to cognitive decline and neurodegenerative damage (Widmann, n.d.). A UK Biobank study found that Covid19 resulted in reduced size of the limbic regions, specifically the olfactory network and parahippocampal cortex, when comparing participants who had Covid-19 with controls (Douaud et al., 2022). Other studies have reported reduced functional connectivity in praecuneus (Li et al., 2023), prefrontal cortical alterations linked with slower responses in cognitive tasks (Clemente et al., 2023), and changes within entorhinal cortex linking anosmia symptoms and memory deficits in pwLC (De Luca et al., 2022), mirroring the prevalence of olfactory deficits in Alzheimer's disease (Chapuis et al., 2013).

The hippocampus, which plays a fundamental role in learning and memory processing, can be affected by neurological disorders and is more sensitive to CNS inflammation than other areas within the brain (Kraynak, 2018). Micro-structural and functional alterations to the hippocampus have been associated with memory loss in Covid-19 patients (Lu et al., 2020). This may be because even mild hypoxia, which may be present but asymptomatic during Covid-19 infection (Brouqui et al., 2021; Dondaine et al., 2022), can lead to amnesia and ongoing memory impairments (Stamenova et al., 2018) as well as well as hippocampal damage (Addante, 2015), (for review see (Hannula et al., 2007; Henke, 2010) and atrophy (Perosa et al., 2020). In addition to hippocampus, memory processing relies on other medial temporal lobe structures (rhinal cortices, parahippocampal cortex) and frontal cortical regions (Elhalal et al., 2014). For example, lesions in the dorsolateral prefrontal cortex can impair working memory and the ability to perform on delayed response tasks, as well as affect item and source memory (Hathaway & Newton, 2025; Stuss & Benson, 1987), which are commonly reported as issues in pwLC. The evidence to date appears to suggest that pwLC have structural or functional alterations in entorhinal cortices (De Luca et al., 2022); prefrontal cortices (Clemente et al., 2023) and possibly also parahippocampal cortices (Douaud et al., 2022), although this may be secondary in severity to the hippocampal damage reported.

Long Covid Literature

This section reviews cognitive domains in turn to provide a snapshot of some of challenges faced by pwLC and summarises findings from existing research. LC literature has been reviewed based on the neurocognitive domains, using the DSM-5 approach (Sachdev et al., 2014). The domains that will be reviewed are perceptual-motor function, language, learning and memory, attention, executive function and social cognition.

While the long-lasting cognitive impact of LC is complex, a growing body of research has explored the impact of LC on various cognitive domains. Emerging evidence suggests that cognitive impairments in LC are heterogeneous, meaning that individuals may experience deficits in different domains and to varying degrees of severity (Hampshire et al., 2024; Rodriguez-Morales et al., 2023).

Perceptual-Motor Function

Perceptual-motor function controls the ability to integrate information, such as visual and auditory information, with motor output to coordinate movement and interact with the environment (Vidal & Lacquaniti, 2021). This domain involves multiple cognitive processes, including perception, spatial awareness and motor planning. Deficits in this domain can impact upon coordination, balance and motor skills both fine and gross. There has been research suggesting that pwLC have impairments in perceptual-motor functions which can contribute to the everyday functioning, such as fine motor skills including ability to button clothing, writing and typing (GarciaSanchez, et al., 2022). Furthermore, issues with reduced coordination, instability while walking and balance deficits have been common (Ortelli et al., 2021). Perceptual motor functions are reliant on reaction times which have been shown to be delayed in pwLC (Llana et al., 2024) offering potential support for reduced speed of processing.

In a cross-sectional online study, pwLC (*N* = 105, mean age 46 years and 82% female) were matched by age and sex to a control group (N= 105) to learn a sequential motor skill over two consecutive days (Hayward et al., 2024). A pre-pandemic control group (*N* = 105) was also included for comparison. Performance of early learning was comparable between all groups of participants, however, typing speeds were slower in pwLC compared to controls. The study also concluded that pwLC showed reduced consolidation , which may be evidence for deficits in procedural memory.

Linked to perceptual motor function is speed of information processing. This is defined as the efficiency in which an individual can perceive, understand and therefore respond to information (Nettelbeck & Wilson, 1997) and is linked to cognitive functioning (Ebaid et al., 2017). Faster processing speeds enable individuals to perform tasks more quickly and efficiently, while slowed processing can result in cognitive fatigue, reduced more error prone cognitive performance and impaired decision-making. Research suggests that processing speed may be particularly impaired in younger individuals with LC (under 50 years of age), as evidenced in several studies (Delgado-Alonso et al., 2022; Herrera et al., 2023; Krishnan et al., 2022), which found slower processing speed in younger participants compared to older individuals.

In a study which employed the BrainCheck web-based neuropsychological assessment, found that males with LC exhibited more pronounced deficits in processing speed than females (Henneghan et al., 2022). Augustin et al. (Augustin et al., 2021) propose that fatigue in pwLC is caused by hypoactivity within the arousal network, which is reflected in the slower processing in patients. This was supported by research by Martin and colleagues (2024) with eighty-eight participants who had LC for an average of 13 months, who underwent neuropsychological assessments and questionnaires to evaluate all cognitive domains. The Test of Attentional Performance (TAP) computerised assessment was used, alongside the Neuropsychological Assessment Battery (S-NAB). Seventy-seven participants completed a follow-up six months later. It was found that pwLC had longer reaction times in alertness and attention, which remained at the six-month follow-up with no statistical improvement. Within the neuropsychological assessment, attention and executive function domains were assessed, which rely on speeded performance, and these were below normal for the pwLC. Executive functions refer to a set of high-level cognitive processes that enable individuals to plan, make decisions and problem-solve (Nemeth & Chustz, 2020). However, there was no significant difference to controls with regards to task accuracy. Subdomain scores for perception and memory which relied more on accuracy rather than speed were both lower for pwLC. Task accuracy measures relying less on speed performance were not or less affected.

Hampshire and colleagues collected data from ‘The Great British Intelligence Test’ to compare cognition between participants who had contracted Covid-19 virus and controls who had not (Hampshire et al., 2021). In a large-scale study, using over 81,000 participants, cognitive tests administered using ‘Cognitron’ included spatial problem solving, digit span and target detection to give a global cognitive performance score. Questionnaires on demographics, lifestyle and mood were also collected. The authors concluded that there were cognitive deficits across domains and slower response times, as well as a significant effect of cognitive underperformance in those who depended on medical assistance for Covid-19 related respiratory symptoms. Furthermore, those with more severe Covid-19 (requiring hospitalisation) showed substantial global performance deficits, whereas those who were treated at home (no medical assistance required) had a small significant global performance deficit, but deficits were present, nonetheless. They also found that individuals whose symptoms had resolved within 12 weeks had only mild cognitive deficits compared to controls. However, individuals with persistent symptoms showed more significant cognitive impairments. Memory, reasoning and EF tasks were most affected in those with unresolved symptoms. The study also observed a correlation between specific cognitive task scores and self-reports of brain fog or poor memory in the two weeks leading up to testing. Hampshire and colleagues relied on self- reported Covid-19 and symptom severity which has the potential for inaccurate infection history. The study provided global cognitive scores which may not represent more specific cognitive process. However, despite these limitations the scale of the dataset provides some early evidence of cognitive differences in pwLC. Other studies have found that individuals with more severe memory impairments tend to have slower cognitive response times (Jennings et al., 2022).

A smaller scale study by Hampshire and colleagues (2022) has supported the idea that Covid-19 survivors have a slower response time on cognitive testing for verbal reasoning and processing speeds when looking at test scores for 46 LC participants all who had been hospitalised and/or in intensive care. Furthermore, they suggested the magnitude of cognitive loss is the equivalent to losing 10 IQ points, evidencing the potential impact on cognitive functioning. The authors suggest that the severity of the acute Covid infection was a good predictor of cognitive deficits, e.g. the more severe the acute infection, the more severe the cognitive deficits attributed. However, they did conclude a limitation of the study was that findings from participants who had been hospitalised does not take into account the cognitive performance of thousands of people who have had Covid-19 and/or struggling with LC who did not require direct hospitalisation.

Language

Language is a complex cognitive function that enables communication through the comprehension and production of verbal and written speech (Semin, 1998). Language involves multiple neural networks and is thought to be predominately within the left hemisphere of the brain, including Broca’s area, which is responsible for speech production, and Wernicke’s area which is involved in language comprehension. However, with further research into language over the last three decades, a new model of the functional neuroanatomy of language has been developed (Nasios et al., 2019), consisting of two interacting networks, one ventral for language comprehension and one dorsal for language production.

Language in pwLC has been described as the most understudied cognitive domain (Bertuccelli et al., 2022). In an attempt to address the lack of research, a study explored language skills in 41 participants with LC (Cummings, 2024). Participants were assessed twice using different language tasks. The results revealed that pwLC had impairments in both immediate and delayed verbal recall, as well as verbal fluency and spoken language. Cummings suggests these deficits add to the difficulties in pwLC returning to work and the need for speech services to address these difficulties. This work supports previous research, that examined records of pwLC who had been referred to NHS services (Chalmers et al., 2023). Data was collected from retrospective service evaluation of two trusts. Cognitive communication problems were found in 52% of patients in one NHS trust and the second NHS trust had 14% of patients with cognitive communication difficulties. The difference was due to the availability and access to a multidisciplinary team, including those with specialist skills in cognition communication, and the differences across services showed variation in how cognitive communication support was delivered. These findings highlight the potential benefit of a multidisciplinary approach for pwLC. Other research investigated the domain of language and found that 16% of participants had difficulties with word finding (Woo et al., 2020). The participants had significantly reduced scores comparatively to controls for concentration and language tasks. Gilheaney and colleagues (2024) also reported that 96% of pwLC in their study had communication difficulties and swallowing difficulties were reported by 73% of participants.

Comprehension and production of language rely on other aspects of cognition, such as memory, attention and executive function (Nasios et al., 2019). Deficits in language function can manifest as aphasia, a difficulty in speaking or understanding language and word-finding difficulties, which has been reported in individuals with LC (Cummings, 2024; Woo et al., 2020). These impairments can significantly impact communication, social interactions, and therefore overall quality of life (Cummings, 2024).

Learning and Memory

Learning and memory are essential cognitive components that allow individuals to acquire, store and retrieve information. Memory can be further divided into different types, including short-term, long-term, implicit and explicit memory (Cowan, 2008). These processes play a critical role in day-to-day functioning to support an individual's ability to retain and recall information, follow instructions, plan, solve problems and make decisions.

A recent systematic review offers a comprehensive analysis of current research on learning and memory in pwLC (Llana et al., 2024). Much of the previous research has focused on comparing memory performance between pwLC and healthy controls (Aretouli et al., 2025; Crivelli et al., 2022; Ferrando et al., 2022; Ferrucci et al., 2021; Garcia-Sanchez et al., 2022; Mattioli et al., 2021; Zhao et al., 2024). The review found that over a third of participants reported memory deficits, highlighting the significant impact these cognitive difficulties have on pwLC's awareness of their altered memory abilities. Conversely, for non-hospitalized, younger patients (mean age of 43), 53% of participants experienced short-term memory problems, alongside reduced quality of life and increased fatigue (Graham et al., 2021).

Interestingly, 84% of the studies reviewed in the Llana and colleagues (2024) analysis used a single neuropsychological assessment, conducted within nine months of the acute infection (Crivelli et al, 2022; Ferrando et al, 2022; Ferrucci et al, 2021; García-Sánchez et al, 2022; Mattioli et al, 2021; Vannorsdall et al, 2022), thus the long-term trajectory of symptoms, cognitive performance and their manifestation were not explored. Only two studies included repeated cognitive assessments up to 12 months post-infection (Cecchetti et al., 2022; Ferrucci et al., 2022), indicating a gap in research on the long-lasting cognitive effects in pwLC. Longitudinal data suggests that verbal memory may improve over time (Cecchetti et al., 2022; Ferrucci et al., 2022) but there is still limited evidence on the trajectory over time.

Cognitive impairments in pwLC have often been linked to self-reported symptoms such as brain fog or poor memory (Hampshire et al., 2024). These cognitive difficulties are likely associated with underlying neuropsychological changes (Ortelli et al., 2021). While individuals aged 45 to 54 years are at a higher risk for developing LC (Thompson et al., 2022), cognitive dysfunction has been observed across all age groups, and even among those who do not have a formal LC diagnosis (Davis et al., 2021; Hampshire et al., 2024). Research suggests that memory function in pwLC may be influenced by factors such as the severity of the acute infection, the presence of persistent symptoms, hospital admission, the duration of hospitalization, and whether intensive care unit (ICU) treatment was required. For example, Aretouli and colleagues (2025) found significant memory impairments in patients who had required intensive care during their acute infection, suggesting that severe acute illness has a long-lasting impact on memory.

Research by Guo and colleagues (2022) examined cognitive impairments in severe cases of LC, comparing them to individuals with milder cases. Their Multiple Linear Regression (MLR) analysis showed that neurological symptoms (e.g., disorientation, delirium and visual disturbances) were strong predictors of memory function.

Additionally, fatigue, gastrointestinal issues, respiratory symptoms, and dermatological problems were also found to correlate with cognitive deficits, which led to the authors defining LC symptom cluster types as discussed herein. Memory and executive function impairments were most pronounced in those with neurological symptoms and fatigue. This study also revealed language and verbal memory difficulties, which aligns with other studies describing similar self-reported cognitive deficits. A limitation of the study was its online methodology, which lacked researcher oversight to account for potential data quality issues. The authors recommended future research be conducted in controlled settings where researchers can ensure the integrity of the data collection process.

Attention

Attention is a critical cognitive function that allows individuals to focus on relevant information while having the ability to filter out distractions in the world around them. An inability to focus attention can not only be frustrating but also reduce quality of life (i.e. not be able to focus on enjoyable tasks such as reading) (Lavie, 2010). Attention plays a fundamental role in other cognitive domains including working memory (Cowan et al., 2005) to enable focus and the ability to switch tasks. Types of attention include sustained attention, the ability to focus on one task for a period of time for example to read a book: divided attention, the ability to process multiple tasks simultaneously such as cooking and holding a conversation, and selective attention, the ability to concentrate on a specific task while filtering out distractions such as working in a noisy environment. Attention deficits, such as divided attention and attention-concentration, have been reported in pwLC (Graham et al., 2021; Jaywant et al., 2021; Woo et al., 2020; Zhou et al., 2020)

Executive Function

These functions are primarily thought to be associated with the frontal lobes of the brain, specifically the prefrontal cortex. Damage to prefrontal regions has been observed in pwLC (Braga et al., 2023), thus, it would be reasonable to suggest that executive function may be impaired for some pwLC, which has been explored. Due its nature, an executive function deficit may also impact ability to work, which in turn could reduce quality of life.

Executive functions are also responsible for inhibition, self-control, working memory and cognitive flexibility (Diamond, 2013). A systematic review identified executive functions as the most commonly impaired cognitive domain in pwLC (Nasir et al., 2025), aligning with previous findings (Bertuccelli et al., 2022; Delgado-Alonso et al., 2022; Krishnan et al., 2022). Additional studies have confirmed executive function deficits in LC patients (Garcia-Sanchez et al., 2022; Mazza et al., 2021). Herrera and colleagues (2023) observed 85% of the 214 participants had severe impairment of executive function, which was measured using a range of neuropsychological tests administered online via Zoom. Participants were compared between those who had been hospitalised during their acute Covid19 infection, and those who had not. The authors reported no significant differences on any demographic characteristic or neuropsychological tests, with the exception of age, such that the older participants had required hospitalisation significantly more than the younger participants. These results offer support to hypothesis that LC deficits are not a direct consequence of a severe acute infection alone. Eighty-five percent of participants were impaired in at least one of executive function task and, interestingly, they found that the older participants in the sample (range was between 26 to 64 years with a mean age of 47 years) were less impaired compared the younger participants who were of working age. This suggests that the working age population are at risk of experiencing long-lasting symptoms and reduced cognitive performance. A systematic review (Fanshawe et al., 2025) examined 66 studies across 16 countries, and identified executive function as the most frequently tested domain in LC research. Executive function can also impact on other cognitive domains including attention, language and memory (Miskowiak et al., 2022).

A systematic review (Tavares-Júnior et al., 2022) also aimed to explore potential relationships between a diagnosis of Covid-19 and cognitive deterioration, such as dementia, mild cognitive impairment (MCI), and subjective cognitive decline (SCD). Although the large variety of cognitive assessments used was identified as a limitation which may question the external validity of the findings, the study revealed that the domains most affected included executive functioning, memory and processing speed. However, although high cognitive impairment was found, the researchers were unable to determine whether this was indeed due to LC or a possible neurodegenerative disorder, as most studies included in the review had included hospitalised patients and could not confirm if cognitive impairment was caused by factors other than Covid-19.

Social Cognition

Social cognition refers to processes ranging from decision-making, which overlaps with executive function, social understanding and social perception, processes that enable evaluation of others' behaviours and intentions (Arioli et al., 2018) to have successful social interactions and achieve social goals (Barlattani et al., 2024). The prefrontal cortex supports decision-making, recognition of own abilities, and social behaviour (Dean, 2025), which has shown to be impaired in some pwLC (Peltz et al., 2011).

Social cognitive impairments have been documented in neurodegenerative diseases and following acquired brain damage (Arioli et al., 2018). Such impairments can impact on interpersonal relationships (Henry et al., 2016) and increase perception of social isolation (Arioli et al., 2018). Anosognosia, the lack of awareness of one's own impairments, is commonly seen in patients with Alzheimer's disease (Kotler-Cope & Camp, 1995), and people with traumatic brain injury. Research has indicated, in some people post-infection, anosognosia was associated with greater memory impairments (Voruz et al., 2022). Furthermore, it was suggested that participants who did not report neurological effects of LC (due to the anosognosia), had associations between episodic verbal memory and dorsal attentional networks, and suggested that lower connectivity was related to poorer memory performance.

Longitudinal Trajectory

There remains a significant gap in research measuring the long-term effects of LC on cognition over time, thus there are no clear implications of how to support this population. A mixed-methods systematic review (Diar Bakerly et al., 2024) concluded that literature lacks evidence of the persistent nature of LC for people living with it beyond 18 months. The systematic review was conducted in two parts; part one which was a meta review of 19 systematic reviews and part two which examined 46 studies between July 2022 and October 2022.

One longitudinal study measured cognitive function using the Montreal Cognitive Assessment (MoCA), at four different time intervals, two before the pandemic and the other two at six and 18 months post-acute infection (Del Brutto et al., 2022). Covid-19 patients (*N* = 50) and those who had not had Covid-19 (*N* = 28) were included. Six months post-infection, Covid-19 participants had a decline in MoCA scores, which was reversed after an additional year during follow-up. The findings, as suggested by the article title ‘Cognitive sequelae of Long Covid may not be permanent’, indicate that the impact of Covid-19 on cognition is not long-lasting.

Another longitudinal study explored different severities of Covid-19 in three 45-day intervals post-infection (Afzali et al., 2024). Participants were categorised into a ‘mild’ group (*N* = 112), a ’moderate’ group (*N* = 67) and a further 79 participants were assigned to the ‘severe’ group. Severity grouping was determined by hospital records. The study captured various psychological aspects including depression, anxiety and stress and repeated the Paced Auditory Serial Addition Test (Gronwall, 1977) to measure working memory, reaction speed and sustained attention. Although participants had a lower correct response rate compared to healthy controls, there was an improvement noted over time. However, the results were not published for any other cognitive measure except correct response rate so the full results remain unclear.

A longitudinal study explored cognitive and other symptoms, and cognitive performance in 187 LC patients compared to controls (*N* = 207). Participants were followed up over nine months (Yeung et al., 2025) and were divided into severity groups, using a method similar to that used by Afzali and colleagues (2024). At the initial assessments, participants were asked to describe the first three weeks after their acute infection. Based on this, 48 participants were assigned to the 'Recovered' group, 61 were assigned to the 'Ongoing-mild / moderate' group and 78 participants were assigned to the 'Ongoing-severe' group. Covid-19 related questionnaires and cognitive tests, including a word list recognition memory test, pictorial associative memory test, a fluency test, the Wisconsin Card Sorting Test (Grant & Berg, 1948) and a 2D mental rotation task, were administered at the initial assessment. The same tests, with the exception of the 2D mental rotation test, were used at all follow up sessions. The scores for these cognitive tasks were separated into five outcomes areas: memory response times, memory performance, category fluency, executive function response times and executive function performance. The study concluded that cognitive and neurological symptoms persisted over time and there was a lack of improvement in symptoms in the Ongoing-mild / moderate' and 'Ongoing-severe' groups. Memory, accuracy and speed was consistently impaired in all groups, particularly in the 'Ongoing-severe' group.

Ferrucci and colleagues (2022) followed up hospitalised participants (*N* = 76) over a 12-month period. The neuropsychological assessments, including the MoCA and a battery of tests, concluded that at the 12-month follow-up there was significant improvement across all domains, particularly verbal recall, memory and speed of information processing, whereby there were improvements in 50% of participants. Similarly, Huang and colleagues (2021) reported a decline in cognitive symptoms from 68% at six months post infection to 49% at one year. Additionally, the research highlighted that females with more severe acute Covid-19 infections experienced greater cognitive difficulties than males.

Contradictory results were presented in a systemic review (Han et al., 2022) which examined several follow-up studies for pwLC. The review concluded that cognitive deficits, specifically memory deficits, were only found in 19% of participants at a 12month follow-up. In another study, assessing 160 participants who had been hospitalised six months prior, concluded that all results on MoCA screening were abnormal results compared to a sample of people discharged from a Covid-19 ward (Cristillo et al., 2022), whereas Mattioli and colleagues (2021), at a four-month follow-up, reported that 118 out of 120 participants had normal neurological examination results and a second four-month follow-up study reported cognitive deficits in 58% of participants, particularly in verbal memory (Méndez et al., 2022).

Another study conducted a 12-month follow-up with 171 participants aged between 23 and 83 years (Méndez et al., 2022) reported that 73% of participants had at least one persistent symptom; fatigue (48.5%) and memory complaints (32.2%) were the most common ongoing issues, with performance on verbal fluency and immediate memory recall being the most affected cognitive domains. Neurocognitive dysfunction, defined as impairments in neuropsychological tests when results were adjusted for age and education, was observed in 46% of participants. Low scores on QoL were prevalent one year after infection. However, this study focused on patients who had been hospitalised during the acute infection, meaning the findings may not be fully generalisable to individuals who did not require hospital intervention during the acute phase.

In a large longitudinal Covid-19 study conducted in China, Lui and colleagues (2022) followed up over 1400 Covid-19 participants, performing neuropsychological testing at six-and twelve-months post-infection. The authors found that individuals who had contracted Covid-19 demonstrated significantly higher rates of cognitive decline over time compared to a control group. Although this study did not specifically investigate LC, the findings support the growing literature suggesting that cognitive impairments may persist well beyond the acute phase and are prevalent for at least 12 months following a Covid-19 infection.

Another longitudinal study of LC used neuropsychological tests including the Mini Mental State Examination (MMSE; (Folstein et al., 1975), the Trail Making Test

(Reitan, 1958) and others to explore cognitive impairments, alongside collecting data on QoL (Diana et al., 2023). At the first data collection, six-months post-infection, there were 21 participants, of whom 52% showed cognitive deficits in at least one domain. The most impaired domain was verbal memory and long-term memory was the second most common, with impairment in 24% patients. Nineteen participants were followed up and repeated neuropsychological assessments at 12 months. Sixteen percent had cognitive deficits in at least one domain. Finally, participants were followed up again at 22 months, the final data collection, where 16 participants remained in the study. Twelve and a half percent of participants still demonstrated at least one cognitive deficit, however, when comparing to the first and second data collection points, the overall frequency of impairments had decreased. This longitudinal analysis demonstrated improvements in verbal and non-verbal memory and the reduction of other cognitive deficits 18 months after infection. However as with most longitudinal studies, the follow up rate dropped at each time point, thus the subsequent samples may not be representative of the starting sample. Nevertheless, the improvement noted at 16 and 22 months could suggest recovery over time. An additional response time test that was implemented at 16 and 22 months, indicated a reduction in alertness / concentration in patients, thus concentration problems could also have attributed to the scores, however this was not captured from the start of the study. This highlights the benefit of computerised testing of attention, as they are more sensitive than conventional paper and pencil neuropsychological tests, where reaction time cannot be measured as accurately. This measure may help to get an insight into the participants concentration and effort during a task.

Llana and colleagues recruited 42 working age LC participants suffering with anosmia to a novel study measuring the consolidation of declarative and procedural learning (Llana et al., 2022). The participants were assessed up to 28 months post Covid-19 infection. Participants completed a LC questionnaire and a selection of neuropsychological assessments, including the Mirror Tracing Test (MTT) to explore procedural memory, the Paired-Associate learning (PAL) test from the Wechsler Memory Scale (WMS-II; Wechsler, 1945) to explore declarative memory and the MoCA, over two days. The results showed that pwLC had lower cognitive scores compared to controls, which were borderline to the suggested cut-off of 26 points for impairment, however, the scores were not considered abnormal cognitive functioning, as memory impairments seen in declarative memory may have been reflected in the global index score. The authors concluded that the MoCA scores reflect specific declarative memory impairment, rather than widespread impairment. This suggests that screening tests such as the MoCA may fail to identify subtle neuropsychological deficits. The study concluded that long-term retention of both types of memories was more at risk, than the acquisition of memory for pwLC. A further interesting finding of this research for pwLC presenting with anosmia, provides scope for the suggestion that olfactory dysfunction can be associated with the impairment of brain regions such as the medial temporal lobe (Llana et al., 2022). This poses further questions as to whether impairments in long-term memory retention may be linked to disruption in the hippocampus.

Neuroimaging research has demonstrated hippocampal activation during both recognition and recall tasks (Stark & Squire, 2000). However, activation alone does not establish that the hippocampus is necessary for these processes. Evidence from lesion studies has traditionally supported a dual-process account of recognition memory, in which the hippocampus is considered critical for recollection and recall, while familiarity-based recognition may be supported by surrounding medial temporal lobe structures (Holdstock, 2005). Within this conventional framework, the hippocampus is therefore viewed as primarily supporting explicit, recollective memory.

However, emerging work has begun to challenge this suggesting that the hippocampus may contribute to a broader range of memory processes than previously assumed. Paradigms designed to dissociate recollection and familiarity, such as the Addante recognition task (Addante et al., 2012) have produced findings consistent with hippocampal involvement in recognition processes that are not easily explained by recollection alone.

Rass and colleagues (2022) conducted a longitudinal study with a three, and a 12month follow-up using the MoCA to assess cognitive performance with 76 patients (mean age of 54 years). LC symptoms were reported by 59% of participants and these ranged from fatigue (38%) to impaired sensation (16%). The MoCA revealed cognitive impairment was prevalent in 23% of participants after three months, and 18% of participants at one year. However, this study did have a high dropout rate (44%) at the 12-month follow-up, which may have limited the ability to detect significant improvements in cognitive function.

Another longitudinal study focused on investigating the impact of LC on physical and mental health and collected data at three assessment points (Vallée et al., 2025). The initial was at three months, 12 months and 42 months post-infection. Assessments included surveys, health questionnaires, anxiety scales and Impact of Events Scale-Revised (IESR; (Weiss, 2007), with a clinical symptom review at the three and a half year follow-up. Eighty five participants remained at the third assessment (*N* = 149 at the initial assessment and *N* = 94 at the one-year assessment), 25% of whom reported persistent symptoms fatigue and ‘crashing’ following activities were among the most frequently reported symptoms. Physical health scores increased between the initial assessment and the third assessment; however, for those with persistent symptoms they were significantly lower than for those whose symptoms had reduced. Furthermore, participants at the third assessment were likely to meet the criteria for depression, compared to those without LC, highlighting the effect on mental health with continued LC. The study concluded that the results of the persistent nature of LC were comparable to those observed in other studies that had followed patients longitudinally for one year (Huang et al., 2022; Kim et al., 2023), evidencing the persistent nature of LC. However, this longitudinal study did not measure cognitive performance.

One hundred and eighty pwLC were followed longitudinally for 23 months post-acute infection (Helmsdal et al., 2022). One hundred and seventy participants remained at the last follow-up session. The mean age was 40 years and just over half (54%) were women. This study interviewed participants by phone, and their symptoms were assessed using questionnaires at enrolment, both the acute symptoms and long-lasting ones. As the long-lasting neurological impact of Covid-19 was not known when data collection began, participants were only asked about memory and concentration at the last follow-up session. Sixty-five participants (38%) reported one symptom, 52 participants reported one or two symptoms and 13 participants had three or more symptoms, at the final session. The most commonly reported symptom was fatigue, which was reported by 22% of participants. At the final session, 129 participants (76%) reported feeling fully recovered.

Given the uncertainty and mixed results surrounding LC long-term effects, longitudinal studies are critical to explore and better understand how cognitive symptoms and performance change over time.

Methodology in LC research

Cognitive deficits in pwLC have been delineated with cognitive screening tools, with the Montreal Cognitive Assessment (MoCA) being one of the most widely used measures (Amalakanti et al., 2021; Del Brutto et al., 2021; Gautam et al., 2022; Piloto et al., 2021; Rass et al., 2021), which was confirmed in a recent review (Navarro et al., 2025). Across studies, MoCA identified varying levels of impairment across cognitive domains, predominately executive function, memory (both immediate and delayed), and processing speed (Amalakanti et al, 2021; Del Brutto et al, 2021; Gautam et al, 2022; Hampshire et al, 2024; Ortelli et al, 2021; Rass et al, 2021). A systematic review (Tavares-Júnior et al., 2022) explored neuropsychological impairments in pwLC, on a large range of cognitive assessment tools, to identify the cognitive domains most likely to be affected. This demonstrated the wide use of the

MoCA with pwLC, with 50% of studies in the review employing the MoCA. While the MoCA is a widely used cognitive screening tool, useful for initial examination, it may lack the sensitivity to detect subtle but clinically significant cognitive deficits (Crivelli et al., 2022) in mildly affected patients or high functioning patients who may lose function, but still score within a normal range (Coen et al., 2015). The reliance on brief cognitive screening measures rather than comprehensive neuropsychological assessments may lead to an underestimation of the prevalence or severity of cognitive impairments in pwLC. Furthermore, the authors of the systematic review pointed out that, to date, no studies had employed comprehensive assessments using a cognitive battery assessment comprising multiple domains, highlighting that further research is required to explore the most consistently affected cognitive domains (Tavares-Júnior et al., 2022). The comparison of self-reported cognitive complaints with objective neuropsychological test performance is essential to better understand the nature and impact of cognitive deficits in pwLC.

Other assessments that have been employed in LC research include the CogState Cognitive test Battery (CSCTB: Cogstate Ltd, 2019), demonstrating deficits in memory and concentration (Darley et al., 2021) and The Brief Memory and Executive Test (BMET; (Brookes et al., 2015) has been used to explore working memory impairments (Jaywant et al., 2021). Miskowiak and colleagues (2021) combined the Cognitive Failure Questionnaire (CFW; (Broadbent et al., 1982) and the Screen for Cognitive Impairment in Psychiatry Danish Version (SCIP-D, Purdon, 2005) and found cognitive impairment in 65% of participants. However, it is important to note that this finding is unlikely to be generalisable to the whole LC population due to the small sample size (< 40 participants) and differences in acute care and vaccination rates across populations that may affect comparability between countries.

Other studies have used digital questionnaires and telephone surveys to explore cognitive complaints among pwLC (Guo et al., 2022; Mcloughlin et al., 2020; Ziauddeen et al., 2022). While these methods are a good method for patient triaging, some the lack depth provided by in person neuropsychological assessments (Guo et al., 2022). Therefore, the results may not have taken into consideration the quality of data collected, as there were no researchers present to ensure that the attention or engagement of the participants was not compromised by being tested in a remote format, a limitation acknowledged by Guo and colleagues (2022).

There are various other methodological differences in LC research. Some studies have focused solely on hospitalised patients (Carfi et al, 2020; Lu et al, 2020; Wong et al, 2020), or case studies (Hussain et al 2022), while others excluded hospitalised patients (Ziauddeen et al., 2022). Some LC research has lacked specified inclusion / exclusion criteria (Garg et al., 2021; Joshee at al., 2022; Meyer at al., 2022; Pierce et al., 2022), while other has been criticised for lacking specific research questions (Littlefield et al., 2022) and there have been limitations in describing statistical methods (Delorme et al., 2020). In group studies, samples sizes have varied from less than 25 participants (Apple et al., 2022; Files et al., 2021, Singh et al., 2021; Sollini et al., 2020), to more than 1000 participants (Dennis et al., 2023; Fancourt et al., 2023, Izzo et al., 2022).

Based on the literature reviewed herein, it is clear that studying cognitive deficits, particularly memory impairments, in pwLC is critical to inform healthcare and promoting wellbeing for this population. As discussed, LC shares similarities with other post-viral syndromes and neurological conditions (Calabria et al., 2022; Guo et al., 2022), thus learning from previous research and investigating the long-term cognitive effects in pwLC, could also provide valuable insights into other post-viral syndromes, with increased knowledge on assessment strategies and interventions. As described herein, individuals of working age are at particular risk of experiencing prolonged cognitive effects. While research efforts to understand Covid-19 and LC are expanding, the long-term impact on cognition, particularly memory function, remains uncertain. Although memory deficits and cognitive impairments are well documented, their persistence and recovery trajectory require further delineation.

In sum, existing literature confirms that memory deficits are common in pwLC, but the severity, duration, emotional and day-to-day impact on people's lives and potential long-term consequences, remain largely poorly understood. An increase in mixed-methods research would be beneficial. This approach would ensure that patients' lived experiences are incorporated alongside cognitive performance, providing a deeper understanding of cognitive dysfunction and its impact on pwLC. Longitudinal studies, diverse participant samples, comprehensive neuropsychological assessments and mixed-methods approaches are all essential in advancing knowledge in this field and ultimately improving the quality of life for pwLC.

Models

There are various memory and chronic illness models which may help to explain and to delineate problems for pwLC. The Multistore Model of Memory (Atkinson & Shiffrin, 1968) describes the use of three distinct memory stores, sensory memory, STM and LTM and explains how information transfers between these stores via attention, rehearsal and retrieval. The MSM has been compared to how technology processes information with input, processing and output (McLeod, 2025). Sensory stores capture information from the senses, and the model explains that sensory memories store how they are received (e.g. sounds, smells and touches). Although this store was thought to be large in capacity, the duration of information held is brief and attention is required for the sensory information to transfer into STM. The model describes STM with limited capacity and elaborates that if information is not actively rehearsed it can quickly fade, whereas LTM has more storage space and can hold information for longer durations. LTM duration is thought to span over decades (Bahrick et al., 1975). When elaborate rehearsal is performed, which involves linking new information and creating associations, memory is more likely to be retained. Various studies have shown the aspects of duration, encoding and capacity to provide evidence for the separate memory stores proposed by Atkinson and Shiffrin. Research exploring rehearsal of memory supports the model as people remember less when rehearsal is prevented, thus suggesting that rehearsal enables information to be stored in LTM (Glanzer & Cunitz, 1966). Research by Miller (1956) and later by Peterson and Peterson (Peterson & Peterson, 1959) supports the idea that STM is limited in duration and is only temporary storage. Furthermore, in the case of patient H.M (an amnesia patient who was unable to store new explicit memories), the suggestion of separate stores for STM and LTM is supported as H.M was unable to make new LTM, but the STM remained intact (McLeod, 2025). As discussed, the model explains that attention and rehearsal are pivotal for memory acquisition and retrieval, which may be impaired in some pwLC.

Although the MSM has been influential in cognitive psychology (Baddeley, Hitch &Allen, 2018), other models have offered further explanations of memory processes. The levels of processing model (Craik & Lockhart, 1972) expanded upon the MSM, emphasizing how the depth of rehearsal affects memory retention. They define depth as “the meaningfulness extracted from the stimulus rather than in terms of the number of analyses performed upon it” (Craik & Lockhart, 1973, p. 48). This model suggests that memory is a result of information processing rather than a structured set of stores as suggested by the MSM. Additionally, the model concentrates on the way in which information is encoded and suggests a deeper level of processing results in easier information recall. They suggest that shallow processing, the encoding of only the physical quality of information or the way it sounds, only involves rehearsal for short term retention, compared to deep processing which uses semantics to encode memories. This was supported by Craik and Tulving (Craik & Tulving, 1975), who confirmed that information that is semantically processed involved elaboration rehearsal and deeper processing, and resulted in more accurate recall, compared to shallow processed information that resulted in less accurate recall. The levels of processing model illustrate the way that elaboration, deeper processing of information, can support memory functioning and leads to better LTM. Deep processing through elaboration rehearsal, can be applied to everyday life by reworking information, linking information and using imagery to encode visually.

Further research has shown that STM and LTM are not singular stores as proposed by the MSM and that memory involves multiple components (Baddeley & Hitch., 1976). Following on from the MSM (Atkinson & Shiffrin, 1968), the Working Memory Model (WMM) by Baddeley and Hitch (1976) may offer some additional explanations into the difficulties of pwLC. The WMM suggests that STM uses multiple components including central executive, phonological loop, visuospatial sketchpad and the episodic buffer (Baddeley & Hitch, 1976). The central executive component is thought to be critical for coordinating and controlling how WM is used and relies on information from the phonological loop and the visuospatial sketchpad systems, which is received auditory and visually. The phonological loop supports short term storage of information in sound form, such as conversations, whereas the visuospatial sketchpad processes visual information as well as spatial information. These systems temporarily store information to enable the central executive to pull upon these resources to assist with decision making and attention, as well as retrieve information from LTM. The episodic buffer, which was added to the model after its initial conceptualisation (Baddeley, 2020), is thought to communicate between the components of working memory and LTM.

Tulving and Pearlstone (1966) described memory with two distinctions; availability of memory, which refers to representations that are stored and available at the time of recall, and accessibility refers to whether the stored memories can be accessed for retrieval. They suggested that cues increased memory recall. Research has linked retrieval of LTM and working memory capacity (WMC) (Unsworth et al., 2012), suggesting that individuals with differing WMC, either low or high, differ in their ability to retrieve LTM. In sum these differences in WMC have been attributed to accessibility, where individuals with low WMC do not search their memory as efficiently as those with high WMC, and it has been speculated that these search differences may be related to the ability to self-generate retrieval cues (Unsworth et al., 2012). There is evidence to suggest that working memory capacity in some pwLC is impaired (Mazza et al., 2021). Working memory impairments are reported to be prevalent immediately after a Covid-19 infection (Becker et al., 2025) but persist over time (Mazza et al., 2021). It has been suggested that when working memory abilities decrease so does the ability to perform daily tasks (D'Esposito & Postle, 2015) which may help to explain the difficulties pwLC have with their day to day lives.

Chronic illness can also impact on a person's sense of self (Van Bulck et al., 2019) and there a various models which help to provide understanding of how this sense of self is affected. The illness identify model (Oris et al., 2016) is divided into four constructs. Engulfment, the degree to which the individual feels their illness is dominating their identity; rejection, in which the individual sees their illness as a threat or unacceptable to the self; acceptance, in which the individual accepts their illness as part of their identity; and enrichment, in which individuals acknowledge how their illness has changed their values and how it has helped them grow within their identity (Helgeson et al., 2006). Individuals may fluctuate between these four constructs depending on their symptom severity and the impact of LC upon their daily function.

The common-sense model of self-regulation (Leventhal et al., 2016) may also provide a theoretical framework to help understand the impact of LC. The model outlines how perceptual, behavioural and cognitive processes are involved when self-managing current and future health concerns. The model has been promoted to support self-management in individuals with chronic conditions to support coping behaviours and adjustment (Leventhal et al., 2016). As discussed herein, pwLC have reported uncertainties and the model may help to educate patients on how they can adjust. Furthermore, Research has shown that LC has reduced independence for some pwLC, with 32% of participants reporting they are unable to live alone without any assistance and 34% reported moderate functional limitations i.e. they were able to care for themselves but not perform usual duties and activities (Ziauddeen et al., 2022).

Overview of the Thesis

This thesis investigates the impact of LC on cognitive function and the trajectory of symptoms and performance over time, to understand both the short and long-term consequences. A mixed-methods approach is used to examine the neuropsychological consequences of LC through both quantitative and qualitative data collection. This thesis explores not only the measurable impacts on cognitive performance but also the lived experiences of individuals affected by LC.

Following this introduction, Chapter Two presents a series of studies investigating cognitive functioning in pwLC, with a particular emphasis on memory. Assessments One, Two and Three use and repeat the same neuropsychological tests and symptom surveys at multiple time points. The chapter then measures and explores the factors associated with and influencing the longitudinal differences between assessments. Finally, the Chapter concludes with a discussion of the cognitive performance data presenting an overview of the long-term effects of Long Covid.

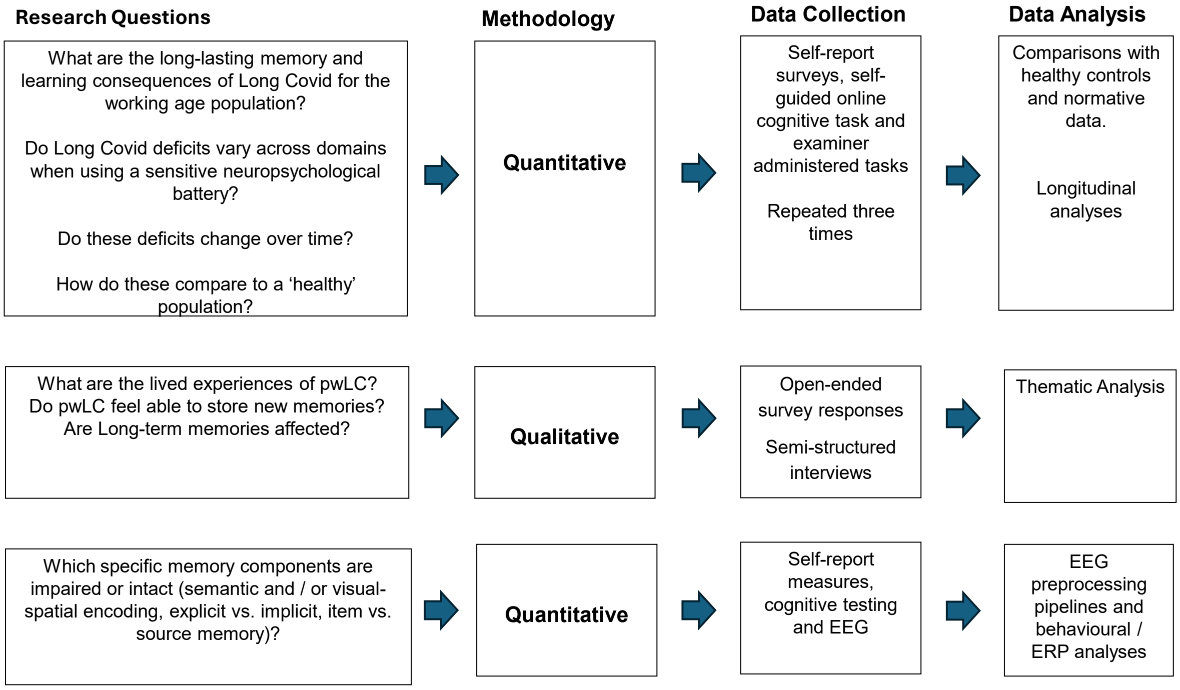
Chapter Three provides results of a thematic analysis of the lived experiences of pwLC, derived from an open-ended response question in a survey that was repeated three times. These findings provide context to the cognitive findings, offering a deeper understanding of the daily struggles faced by individuals living with LC.

Chapter Four examines qualitative data that was collected in semi-structured interviews and was analysed using thematic analysis. This chapter extends the exploration of lived experience by providing deeper insights into participants' daily realities.

Chapter Five outlines a study protocol aiming to delineate the cortical dynamics of memory encoding and retrieval processes in working-age LC patients and matched controls. The study is a registered report planning to use electroencephalography (EEG), event-related potentials (ERPs), and behavioural measures to explore cognitive performance. The chapter details the proposed methodology, data collection procedures and analytical techniques, and offers a rationale for the expected findings based on prior literature.

Chapter Six provides a comprehensive discussion of the findings across all studies, synthesising the evidence to draw conclusions about the long-term cognitive and psychological impact of LC. The chapter also considers the clinical implications of these findings and outlines the interventions and support needed for people living with LC, particularly public awareness to reduce stigma and ensuring that people with LC receive timely and effective care. An overview of the study designs and the research questions are presented in Figure 2.

Figure 2. Overview of Thesis



Research Questions	Methodology	Data Collection	Data Analysis
What are the long-lasting memory and learning consequences of Long Covid for the working age population? Do Long Covid deficits vary across domains when using a sensitive neuropsychological battery? Do these deficits change over time? How do these compare to a 'healthy' population?	**Quantitative**	Self-report surveys, self-guided online cognitive task and examiner administered tasks Repeated three times	Comparisons with healthy controls and normative data. Longitudinal analyses
What are the lived experiences of pwLC? Do pwLC feel able to store new memories? Are Long-term memories affected?	**Qualitative**	Open-ended survey responses Semi-structured interviews	Thematic Analysis
Which specific memory components are impaired or intact (semantic and / or visual-spatial encoding, explicit vs. implicit, item vs. source memory)?	**Quantitative**	Self-report measures, cognitive testing and EEG	EEG preprocessing pipelines and behavioural / ERP analyses

Chapter Two: Longitudinal Studies

Introduction

This chapter describes cross-sectional comparisons between pwLC and controls. Firstly, it provides an overview of the aims, hypotheses, methodology and results of three assessments, whereby cognition and characteristics of LC were explored. It begins with an overview of the methodological choices within these studies. It summarises the research design and describes the materials used within the assessments. Next, it presents results from three assessments that used two different cognitive assessments with pwLC: an examiner administered assessment: the BIRT Memory and Information Processing Battery-II (BMIPB-II) and a self-guided Word Categorisation and Recognition task, at three different times spanning 24 months, from March 2023 to March 2025 with an average of 19 months between the first and third assessment (SD = 1.41).

Next, the results of longitudinal analyses from Assessments One, Two and Three are presented to examine the long-term outcomes for pwLC to compare performance across assessments. Integrating results across assessments allowed for the identification of patterns such as suspected deficits, signs of recovery or areas of stability in memory performance and functioning.

Finally, this chapter concludes with a discussion on how the results inform understanding of LC as a chronic illness and how these the condition manifests over time.

Research Approach

Psychological research typically uses qualitative, quantitative or mixed methods approaches (Plano Clark, 2017; Teddlie & Tashakkori, 2009). As this thesis collects and analyses both quantitative and qualitative data, a mixed-methods approach was adopted. Mixed methods research integrates of data at one or more stages,allowing researchers to address more research questions than using a qualitative or a quantitative approach in isolation or can enhance the findings of research (Tashakkori & Teddlie, 2003). Therefore, mixed methods research can provide a more rounded picture by providence objective (quantifiable) evidence as well as insight into the participants' lived experiences.

Research Aims

The studies in this chapter were exploratory in nature due to the conflicting previous literature rather than hypotheses driven.

Assessment One

This assessment aimed to explore cognitive performance, specifically memory and learning, in sub-tests of a sensitive battery (BMIPB-II) and a digital assessment, a Word Categorisation and Recognition task. The sub-tests of the BMIPB-II and the Word Categorisation and Recognition task were administered remotely to pwLC and to healthy controls. The BMIPB-II was examiner-led, whereas the Word Categorisation and Recognition task was self-guided. During the study design, the decision to use cognitive assessments remotely, over face-to-face assessments, was motivated by the scope of reach of participants to enable a more diverse sample of LC participants to take part. This assessment aimed to capture LC symptoms, measure cognitive performance as well as exploring overall quality of life, fatigue and daily life functioning.

As discussed in the introductory chapter, this research focused on the cognitive impact of LC on a sample of working aged adults. The motivation for this was to provide insight into abilities and explore the extent to which the capacity to work may have been compromised in those who have LC. A negative impact on people's ability to work, could not only be economically detrimental but also impact the wellbeing of the individuals, with a ripple effect to all around them (i.e. relationships, financial burden). It could be expected that the more severely LC disabled an individual, the more likely their work and their quality of life will be affected.

Assessment Two

This assessment aimed to build upon the findings from Assessment one by tracking cognitive performance over time. Additionally, this aimed to explore the other long lasting impacts of LC including symptoms, quality of life and daily functioning to provide a comprehensive understanding of LC.

Assessment Three

This study aimed to extend the findings from previous studies and contribute longitudinal data to the LC literature by repeating assessments that had been administered at two previous timepoints. By using a repeated measures design, this study's primary aim was to track cognitive trajectories over time in pwLC. Additionally, this aimed to capture the potential long-lasting impact of LC impact on symptoms, quality of life and daily functioning.

Methodology

Quantitative Data

Quantitative data can be summarised by collecting numerical data from participants and analysing it using statistical techniques (Jopling, 2019). There are numerous benefits to using quantitative data including its reliability and the ability to produce quantifiable data which can be generalised to different populations (Marshall, 2016). Additionally, quantitative data can support validation or objection to existing theories or research and allows for hypothesis testing. Quantitative data collection was specifically selected for Assessments One-Three and longitudinal analyses of these assessments to enable objective measurements of potential cognitive deficits in pwLC.

Participants

Assessment One

An initial G*power calculation (Faul et al., 2009) for a one-tailed independent samples *t*-test to assess differences between pwLC and healthy controls (e.g., on measures of memory performance or perceived fatigue), with a medium effect size (*d* = 0.5), a *p* value threshold set at .05 and power (1-β) of 0.80, recommended a sample size of 51 participants per group. A medium effect size was chosen because we were expecting at least a medium effect size in our comparison of memory performance between groups. Furthermore, anything less than a medium effect size was not going to be clinically relevant in functional contexts (Cohen, 2013).

A convenience sample of 73 participants was to allow for attrition and any extreme levels of performance that may represent statistical outliers and therefore the need to be excluded from analyses. Of the 73 participants recruited, data from five participants were not included in the final analyses due to incomplete data sets with either not completing both parts of the study (the examiner administered assessment and the self-directed Word Categorisation and Recognition task) or responding that they had not actually had LC on the survey. A final sample of 68 participants was included in the data analyses.

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LC participants were from 10 different countries. 50 participants were from the United Kingdom (75%), one from Brazil (1.47%), one from Spain (1.47%), two from South Africa (2.94%), one from Egypt (1.47%), one from Germany (1.47%), seven from the

United States of America (10.29%), one from Greece (1.47%), one from Poland (1.47 %), two participants were from Norway (2.94%) and one from Ireland (1.47%).

Fifty-five controls for the self-guided Word Categorisation and Recognition task and 49 controls for the examiner administered List Learning and Word Recognition subtests on the BMIPB-II, matched for age, sex and years of education, were recruited. These controls were recruited from social media. Controls were recruited for the BMIPB-II after data collection due to unexpected results (see Results). Table 2 shows all participants demographics.

Table 2. Participant Demographics Assessment One

Demographics	**Long Covid (*N* = 68)**	**BMIPB-II controls (*N* = 49)**	**Digital Word Categorisation & Recognition controls (*N* = 55)**
Sex			
Female	57 (84%)	28 (57%)	35 (64%)
Male	11 (16%)	21 (43%)	20 (36%)
Age (years)	45.2 (12.15)	45.10 (13.58*)*	45.67 (13.24)
Years of education	14.5 (3.25)	15.87 (3.65*)*	16.50 (3.40)

The inclusion criteria for the control participants were 18+ years of age, people who did not have lingering LC symptoms, including ‘brain fog’ and problems with memory or concentration, alongside having access to a computer / laptop to ensure screen brightness and sufficient sound for clarity of the materials.

The inclusion criteria for pwLC were 18+ years of age, people who have had Covid19 and experienced lingering symptoms including ‘brain fog’ or problems with memory or concentration, with either a formal diagnosis of LC or reporting LC symptoms, having access to a computer or laptop. There were no exclusion criteria for Assessment Two or Assessment Three. Participation via mobile phone or tablets was not possible, to ensure that the screen brightness and sound allowed clear presentation of the materials. Each participant was compensated for their time with a £40 Amazon voucher. All participants gave written consent via the Qualtrics survey platform. This outlined the propose of the study, their rights and confidentially procedures.

Assessment Two

Participants who took part in Assessment One were invited to take part in Assessment Two. The inclusion criteria remained unchanged. Participants were from eight countries. Thirty-three participants (71.74%) were from the United Kingdom, six were from the United States of America (13.04%), two were from Norway (4.35%), one was from Brazil (2.17%), one was from Spain (2.17%), one was from Greece (2.17%), one was from Poland (2.17%) and one person was from Ireland (2.17%). Forty-seven participants were recruited for the study, however data from one participant were not included in the analysis due to an incomplete data set, therefore the final sample comprised of 46 participants. The demographic characteristics of participants were as follows, participants were aged between 24-73 years, with a mean age 46.76 (*SD* = 10.97) years and consisted of nine males (19.6%) and 37 females (80.4%). The number of years of education ranged from 10 to 22 years, with an average of 14.58 (*SD* = 3.23*).*

The control groups included in this assessment comprised of the same participants who were recruited for Assessment One, thus the demographic are the same. The use of the data from the existing control sample allowed for consistency in comparative analyses across both timepoints, ensuring that any observed changes in the LC group could be more reliably attributed to between-group effects rather than variability between measurement time points within the control group.

Assessment Three

Participants who had taken part in both studies one and two were invited to take part in Assessment Three. The inclusion criteria remained unchanged. There were no exclusion criteria for study three. Participants were from six countries [Brazil (*N*=1), Ireland (*N* = 1), Norway (*N* = 2), Czech Republic (*N* = 1), United States of America (*N* = 5) and United Kingdom (*N* = 29)], Thirty-nine participants took part in this study. Seventy nine percent of participants (N = 31) were female, the average age was 48.79 (*SD* = 1.29) and the average years of education was 14.56 (*SD* = 3.28). The control group for this study comprised the same participants whose data were collected for the previous assessments. The researcher maintained in on average quarterly contact via email with the participants who had previously taken part in the previous assessments. It is believed that the continued communication helped with engagement and to build rapport.

Ethics

Ethical approval was obtained from the University of Essex for each Assessment (Assessment One ETH2223-0326, Assessments Two and Three ETH2324-0008). All participants for each study gave informed consented that was captured using the Qualtrics platform. To protect confidentiality, participant numbers were used and all data was securely stored on a password protected computer only accessible by the research team (i.e. researcher and supervisors). Participants were informed during the consent process that they could withdraw from any of the studies at any time, without giving any reason and that any data collected up to that point would be securely destroyed upon request. Over the three studies, no participants asked to withdraw their participation or their data. Participants and researchers were not exposed to harm in these studies; however, the researcher did have regular supervision to discuss any issues that might arise from working closely with the LC community. No adverse events or distress to either participants or the researcher were recorded.

Materials

Assessments One, Two and Three

Covid Survey

Participants were asked to complete a Covid survey, created by the research team using NHS guidance on typical symptoms of Long Covid during Assessment One and elements of this survey were repeated in Assessments Two and Three (minus the acute infection details as this was captured in Assessment One). This survey consisted of 16 questions related to the Covid-19 virus including symptoms, both during the infection and longer-term symptoms, any diagnoses participants may have received and any medical aids or treatments they have used to help with symptom management, including the use of medication and social prescribers, who may have referred patients to services. Symptoms were selected from the NHS website (*COVID-19*, 2023) and participants were asked to list their most severe symptoms in order of how these affected their daily lives (from the worst symptoms to least impactful).

Acute Covid-19 Severity

An Acute Severity Index was created by the researchers to help delineate acute Covid-19 infection severity. Higher scores on this index indicate worse acute severity. The index combined two components and which were allocated numerical score as follows:

- Severity of acute symptoms: asymptomatic = 0, had symptoms but they were mild = 1, quite ill, but able to recover at home = 2, hospitalised but not on ventilator = 3, hospitalised and put on a ventilator = 4.
- The number of acute symptoms (such as cough and loss of smell): i.e. no symptoms = 0. One symptom = 1, two symptoms = 2, etc.

Long Covid Severity

A Long Covid Severity Index (LCSI) was created by the researchers to capture severity and impact of LC. Higher scores would indicate more severe LC, as the index would reflect more long-lasting symptoms and more limitations to everyday life. The LCSI was contingent on confirmation of LC either with a formal diagnosis or suspected without a formal diagnosis and was calculated using the following variables:

- The time (number of months) since acute Covid-19 infection (in months) infection at the time of data collection (e.g. five months = 5)
- The number of long-lasting symptoms endorsed (e.g. three symptoms = 3)
- Scores on daily life limitations (e.g. from 0 = no limitations to 4 = severe limitations).

Daily Limitations

Participants were asked to self-rate their daily limitations at each Assessment. This scale is from the Post Covid-19 Functional Status (PCFS) scale used to quantity functional limitations (Klok et al., 2020). The response choices and corresponding numerical codes are represented in Table 3.

Table 3.Daily Limitation Response Choices

Response to Daily Limitations	**Ranking scale**
I have no limitations in my everyday life and no symptoms, pain, depression or anxiety related to the infection.	0
I have negligible limitations in my everyday life as I can perform all my usual duties / activities, although I still have persistent symptoms, pain, depression or anxiety.	1
I suffer from limitations in my everyday life as I occasionally need to avoid or reduce usual duties / activities or need to spread this over time due to symptoms, pain, depression or anxiety. I am, however, able to perform all activities without any assistance.	2
I suffer from limitations in my everyday life as I am not able to perform all usual duties / activities due to symptoms, pain, depression or anxiety. I am, however, able to take care of myself without any assistance.	3
I suffer from severe limitations in my everyday life: I am not able to take care of myself and therefore I am dependent on nursing care and / or assistance from another person due to symptoms, pain, depression or anxiety.	4

Quality of Life

Research suggests LC has a substantial impact to people's quality of life (Davis et al., 2021). To get an indication of QoL in these Assessments, the Quality of Life Scale (QOLS) (Flanagan, 1978) was selected. This scale has 16 items scored on a 7-point Likert scale, ranging from 'Terrible' to 'Delighted'. It was designed for assessing quality of life in populations with chronic illnesses, which makes it ideal to use with pwLC. The QOLS has been shown to be reliable and internally consistent across several studies (Cronbach's alpha between α = .82 to .92; (Burckhardt & Anderson, 2003) suggesting the scale can be confidently applied in research and practice settings. Total scores (sum of all item scores) can range from 16 to 112. Higher QOL scores would indicate higher quality of life. The average total score for healthy populations is around 90 (Flanagan, 1978).

Fatigue Scale

Fatigue is a frequently reported symptom in pwLC which can have debilitating effects on all activities of daily living (Kedor et al., 2022; L. Townsend et al., 2021). To measure fatigue in pwLC, the Chalder Fatigue Scale (CFQ; (Cella & Chalder, 2010)) was selected. The CFQ is a questionnaire with 11 items which are scored on a 4-point Likert scale, ranging from 'less than usual' to 'much more than usual'. This scale has been used in LC research previously (Kedor et al., 2022; L. Townsend et al., 2021) and has shown to be reliable with good internal consistency, with a Cronbach alpha between .86 and .92 (Cella & Chalder, 2010). Previous use of the scale with those with chronic fatigue syndrome (CFS) resulted in an average score of

24.4 (*SD* = 5.8), compared to a healthy sample score of 14.2 (*SD* = 4.6).

Self-Guided Word Categorisation and Recognition Task

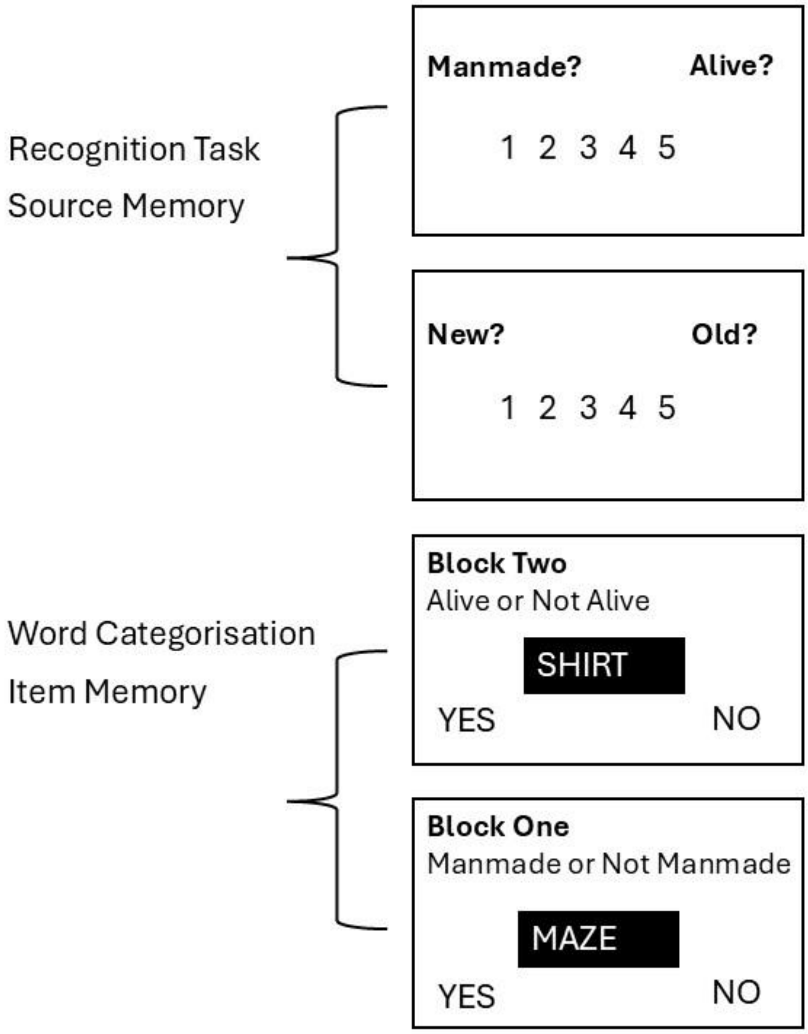
The use of a word categorisation task for testing memory was specifically selected for this research, as it has been previously used with patients with memory loss (Addante et al., 2012) supporting the application in cognitively vulnerable populations. This is relevant to pwLC as memory deficits are heavily reported (Guo et al., 2022). This task was designed to capture multiple stages of memory processing including encoding and recognition, rather than one memory outcome. These processes may be more difficult for pwLC experiencing brain fog, reduced cognition and clarity, rather than a complete memory loss. Accessing encoding and recognition allows a nuanced exploration of memory difficulties in pwLC.

Memory studies that use ‘old/new’ paradigms where performance is dependent on counterfactual reasoning have been criticised in the literature (Brady et al, 2022) and raises questions regarding if such tasks capture episodic memory effectively or measure judgements only. However, word recognition paradigms have been used across cognitive and clinical research (Lezak et al, 2012). The inclusion of semantic categorisation at encoding supports research that shows deeper processing leads to increased memory recall (Craik & Lockhart, 1972). PwLC may demonstrate slow processing and semantic tasks may highlight difficulties in memory functioning.

Semantic categorisation and recognition tasks offer some ecological validity as they resemble everyday tasks such as organising and making judgements, and thus provides a good reflection of how pwLC may complete these tasks in their everyday lives. This is important given that some pwLC often report memory difficulties that interfere with daily functioning.

Following the work by Addante and colleagues (2012), the memory task was divided into two sections. Firstly, a Word Categorisation task was administered for incidental memory encoding, whereby participants were visually presented with two blocks of 65 words. One block consisted of asking if each word represented something ‘manmade’ or ‘not manmade’ such as toy and maze, and the second block asking if the word represented something ‘alive’ or ‘not alive’ such as rat and shirt. Secondly, participants were presented with a recognition task and were asked to select whether they had seen each word before (item memory), and, if they had in which block (source memory). To describe whether they had seen each word before or not, participants were given five response options ‘I’m sure it’s new’, ‘It’s probably new’, ‘I’m not sure’, ‘It’s probably old’ and ‘I’m sure it’s old’ to assess both item memory and confidence in item memory. Once participants identified a word of the list as ‘old’ (one they had seen previously) they were asked to select from one of the five option which were, ‘I’m sure it’s from the Alive list’, ‘Probably from the Alive list’, ‘Guessing’, ‘Probably from the Manmade list’, and ‘I’m sure it’s from the Manmade list’ to assess both source memory and confidence in source memory. The different stages of this task are on shown on Figure 3.

Figure 3. Word Categorisation and Recognition Task



The words in each list (manmade, alive and recognition) were carefully selected from the Medical Research Council Psycholinguistics Database (http://www.psych.rl.ac.uk/MRCPsychDb.html), which provided the linguistic statistics for each word. The average linguistic statistics for each list are displayed in Table 4. The manmade and alive lists were a mix of things that are alive (33 items) and manmade (32 items) to make the set of 65 words for each block. This was to ensure both lists were matched on the characteristics (i.e. concreteness, familiarity, imageability and frequency) and balanced, each containing a proportion of alive and manmade words to prevent the recognition task being too easy due to category cues. The words were presented in uppercase in a white font on a black background. Addante and colleagues (2012) had participants sit approximately 44 inches away from the screen, however as participants did this task independently from their homes in these studies, the distance from screen information was not controlled.

Table 4. Linguistic Statistics for the Word Categorisation and Recognition Task

List	**Concreteness M (range)**	**Familiarity M (range)**	**Image-ability M (range)**	**Frequency M (range)**	**Number of letters M (range)**
Manmade	582.17 (446 - 631)	505.60 (308 - 613)	577.28 (435 - 635)	26.51 (3 - 126)	4.88 (3 - 8)
Alive	582.22 (428 - 654)	505.68 (313 - 644)	577.60 (441 - 642)	26.74 (3 - 131)	4.98 (3 - 8)
Recognition	582.41 (425 - 646)	505.57 (317 - 620)	577.36 (424 - 639)	26.71 (3 - 101)	4.99 (3 - 8)

Examiner Administered Tests

The BIRT Memory and Information Processing Battery II (BMIPB-II) is a sensitive neuropsychological assessment, includes normative data from a sample of adults (Oddy et al. (2019).

For Form 1 the whole normative sample is *N* = 505 (for long delay aspects *N* = 373) and for Form 2 the whole sample *N* = 139 (for long delay aspects *N* = 102). These are matched for key demographic characteristic of the United Kingdom population (sex, education, occupation). The normative data is organised by age group and regression-based norms, available for some sub-tests, that adjust for both age and years of education.

The sub-tests of the BMIPB-II cover a range of tasks including Verbal Fluency, Picture Naming, Description Naming, Figure Recall, Story Recall, List Learning, Word Recognition, Design Learning, Design Recognition, Speed of Information Processing: Motor or Oral, Reliable Digit Span, and Long-Term Forgetting. For the current thesis, the following sub-tests were selected: Story Immediate Recall, List Learning, Word Recognition, Design Learning, Design Recognition, Speed of Information Processing (SOIP) Long Delay Story and Long Delay List. This sub-set of BMIPB-II tasks were selected for a variety of reasons. Firstly, the sub-tests were chosen around the symptoms such as memory and concentration difficulties reported by pwLC, that were evident in research available at the time. Furthermore, practical aspects were taken into consideration to ensure a realistic methodology for online assessments, while considering limitations and following guidance around online testing (i.e. how the information is displayed and ensuring clear differentiation between instructions and presentation of test items). The BMIPB-II has been shown to be sensitive to cerebral dysfunction and it is used in clinical practice across the United Kingdom to aid diagnosis by specialist neuropsychological services (e.g. memory clinics), making it a suitable test for potential dysfunction in pwLC. With permission from the test publisher Brainkind (known as The Disabilities Trust at the time of publication), materials were digitised on Microsoft Power Point for remote online (Zoom) presentation by the researcher. The same sub-tests from the BMIPB-II were administered across assessments, however the BMIPB-II has two alternate forms, so the second form can be used to repeat assessment while controlling for practice effects.

Form 1 was used for Assessment One and Assessment Three and Form 2 was used for Assessment Two. The test manual provides normative data of the BMIPB-II for different age groups; Form 1: 18-30 years, 31-45 years, 46-59 years, 60-69 years and 70+ years; Form 2: 18-45 years, 46-65 years and 66 years or over. At Assessments One and Three, due to the age of most of the participants falling in the 45-59 age bracket, these were the normative results and at Assessment Two the 46-59 age bracket was used for the comparisons. Two versions were specifically developed to allow for re-testing (Oddy et al., 2019). Test-retest reliability in memory research are not very reliable in general (Oddy et al., 2019) however, the BMIPB-II Form 2 has good test-retest reliability. As an example, Speed of Information Processing and List Learning have high test-retest reliabilities (r = .80 and .72). Furthermore, there is evidence to suggest there are no significant differences between performance on Form 1 and Form 2 and no evidence to suggest practice effects.

BMIPB-II Story Recall

For the Story Recall task, participants were read a fictitious story with numerous details. Participants were then asked to recall details from the story immediately after presentation, and again after a short delay (30-40 minutes later). For each correct idea that was recalled, a score of one or two points was awarded, depending on the accuracy and the degree of detail. This was then summed to derive immediate and delayed story recall scores. This was followed up five to ten days later with a call on Zoom in which the participants were asked to recall for a third time to assess long term memory and forgetting (described in more detail in the long delay section below).

BMIPB-II List Learning

A list of 15 words (list A) was read to the participants, who were then asked to immediately recall as many of the words as they could from the list. This procedure was repeated to a maximum five trials or until participants could recall all 15 words for two consecutive trials. The last trial out of the five trials is referred to as A5 in the results. A second list (list B) was then read out and the participants were asked to recall all the words they could from this second (distractor) list. Only one trial was given with this second list. Following this, the participants were then asked to recall again as many words as possible from list A, this is referred to as A6 in the results. Each trial was scored by awarding one point for each correctly recalled word, thus the higher the total score over all the trials the better the recall. There was a total of six recalls for list A and one recall for list B. This was followed up five to 10 days later when the participants were asked to recall any words they could remember from either of the lists to assess long term memory and forgetting (see long delay section below).

BMIPB-II Word Recognition

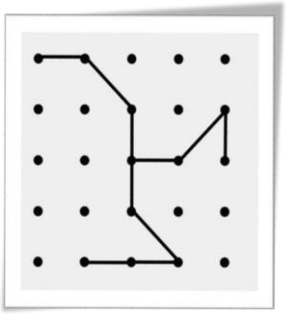
The List Learning task was followed by a forced-choice recognition task, in which the participants were required to identify which of a pair of words belonged to the 30 words that they had previously heard (item memory). The distractor word pairs comprised semantically associated, phonetically similar or random words. The participants were also asked to identify within which list (A or B) the word they had recognised had appeared (source memory). Unlike the list learning task, which was presented orally, the recognition task was presented visually (I. e. the participants were presented with a list containing 30 pairs of words at the same time to identify the List A and List B words on the screen and were asked to respond orally). Each correctly identified word was awarded one point for the word and one point for identifying the correct source.

BMIPB-II Design Learning

Participants were shown a 10-line design (Design A) formed by connecting some of the dots in a five-by-five array, for a total of ten seconds, an example is shown in Figure 4. The participants were then asked to reproduce the design (A) onto a blank dot matrix, from memory immediately after display by using the annotation feature on

Zoom. As in the List Learning task, this procedure was repeated a total of five trials (the same design) or until the participant could reproduce the design accurately and in full on two consecutive trials. A second design (Design B) was then shown, and the participants were asked to reproduce it from memory using a blank five-by-five dot array and the annotation feature in Zoom. Only one trial was given for the second design. Following this, the participants were asked to reproduce the design A again. In total there were seven reproductions of images, five repetitions of design A, one of the design B and a further repetition of design A. The designs drawn by the participants were screenshot for scoring after the Zoom call. Scores for this task were one point for each correct line identified of the design (maximum of 10 points for each design, total maximum for all trials if 70), incorrect lines were not deducted. Prior to data collection with the BMIPB-II, a pilot to evaluate the feasibility of using the BMIPB-II in a virtual format was carried out. This pilot highlighted some technical issues with completing the assessment virtually, including use of the annotation feature on Zoom which was required for this task. These issues were resolved prior to data collection by the researcher requesting support from the technicians from the University of Essex.

Figure 4. Example of Design



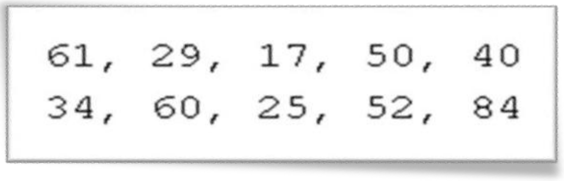
BMIPB-II Design Recognition

Immediately following the Design Learning task, the participants were shown a series of 40 designs and were asked to identify whether each design had been one of the images they had drawn in the previous task or not. When identifying a design as one that had been seen before, the participant was then requested to make a judgement about which design they believed it to be, the first design they had seen several times (Design A) or the second design they just saw once (Design B) to assess source memory. Each correctly identified design was allocated one point and each correctly identified source was allocated one point, the maximum for correct design is 40 and the maximum score for correct source is 10.

BMIPB-II Speed of Information Processing

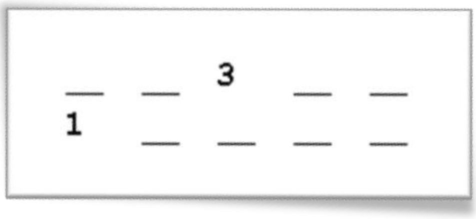
The participants were presented with a slide of sixteen five-by-five matrices, divided into four columns, containing rows of five two-digit numbers, an example can be seen in Figure 5. They were required to work through each row (i.e. 1st row, 2nd row, 3rd row, 4th row then 5th row) from left to right then down in column in order. They were asked to call out the second highest number in each row as quickly as possible for a period of four minutes, each correct number identified was awarded one point. A test of oral speed was also administered in order to calculate a score adjusted for possible individual variation in speech speed (adjusted speed of processing score). Participants were presented with another slide containing random numbers, ranging from one to five, laid out in a spatial distribution similar to that of the targets in the first task (Figure 6). Participants were required to read aloud as many numbers as possible in the allocated time (25 seconds), each correct number identified was awarded one point. The adjusted speed of processing score was calculated as (9.6 X SOIP total X Motor speed) / ([9.6 X Motor speed) – SOIP total] (Oddy, Ramos & Crawford, 2019)..

Figure 5. Example of Speed of Processing



61, 29, 17, 50, 40
34, 60, 25, 52, 84

Figure 6. Example of oral speed



__ __ 3 __ __
1 __ __ __ __

BMIPB-II Long Delay

Participants were asked on the day of the initial assessment if they agreed to a follow up call five to 10 days later, they were told it was a follow up session, to minimise rehearsal. Participants who consented to be contacted again were called and asked to recall as many of the details as they could of the story they were previously told. Following the standardised procedure for this sub-test, participants were first given an opportunity for free recall, then were asked specific questions about the story, and provided with recognition prompts when needed, and if they were struggling to recall any information. Participants were then asked to recall as many words as they could from the two lists of words they were read previously, as well as asked to make judgment about which list they believed each recalled word was from.

BMIPB-II Calculating T-scores for change

The BMIPB-II re-tester program (Oddy, Ramos & Crawford, 2019), provides calculation of retest results for selected subtests including Story Immediate Recall, Story Short Delay Recall, List Learning, Design Learning and Speed of Information Processing Adjusted. The programmes use raw scores, alongside age and years of education, when a participant is tested with Form 1 then retested on Form 2. Retest scores are predicted from initial scores using regression derived from the normative sample (Crawford & Howell, 1998). These scores are standardised and expressed as *T*-scores for change (McSweeny et al., 1993). A *T*-score of 50 indicates performance on Form 2 equivalent to performance on Form 1. Scores below 40 are one standard error below the change mean, and reflect poorer performance at retest, whereas scores of 60 or above are one standard -deviation above the change mean and suggests performance compared to the initial testing.

It is acknowledged that repeating information can create artificial boosting with more exposure on tasks. However, this assessment is a standardised clinical measure and the administration must follow procedures set out in the test manual. Standardised tests commonly include discontinuation rules to reduce participant burden and limit unnecessary exposure once a participant's ability level has been established (Lezak et al., 2012). Therefore, to allow comparison with the normative data and ensure the test was following clinical practice, the assessment adhered to the instruction of the manual.

Procedure

Assessment One

A flyer was distributed online (Facebook , Long Covid support groups, Instagram) or in person (local libraries, conferences and Long Covid clinics) for participants to access the web app study (titled ‘Happy Again’: cHanging memory, Attention, PercePtion and multisensorY integrAtion as biomarkers of functional neurophysioloGicAl INtegrity after Covid-19) which contained 10 tasks including the self-guided Word Categorisation and Recognition task which data from which were extracted for this research. The Happy Again web page displayed participant information and included participation inclusion criteria and a consent form to sign up for the study. Once registered, participants were able to access the materials over a two-week period to complete all the tasks. Automatic reminders were issued to participants during the two-week period. Once all the tasks were completed, participants were sent a £20 reward voucher via email.

Upon completion of the ‘Happy Again’ study, participants were asked to confirm whether they would like to be considered for further research on LC. The participants who confirmed interest in taking part in further research were sent a participant information sheet that provided details of the study involving the examiner administered data collection.

Each participant was sent a detailed participant information sheet via email, outlining the purpose of the study, what their involvement would entail, the voluntary nature of their participation and information regarding confidentiality and data protection. At the beginning of the Zoom call, prior to data collection, the participants were requested to complete a consent form via Qualtrics, which was shared with them in the chat feature of Zoom. Once consent had been confirmed, the data collection began.

To accommodate the personal commitments of participants, many of whom may have been managing ongoing symptoms or balancing work with symptoms, a range of booking slots was made available. These included options during the day, in the evening and over weekends, providing as much flexibility as possible and maximising participation opportunities. Each calendar slot was allocated for one hour, providing time for the researcher to explain the procedure, answer any questions and administer the BMIPB-II tasks.

The Zoom calls between participant and researcher were on a one-to-one basis and lasted between 40 and 70 minutes. The researcher administered the sub-tests of the BMIPB-II in the same order for every participant using Microsoft Power Point. The responses were scored after the Zoom call had finished. A phone call was prearranged with participants approximately five to 10 days after the initial Zoom call.

This was to complete the long delay tasks. The follow up calls ranged from five to nineteen days with an average of eight days since the first session (SD = *2.53*). The data for this study were collected between March 2023 and July 2023.

Assessment Two

The time between the first and second assessment varied between participants, ranging from four to ten months (dependent on the pwLC availability), with an average of 5.5 months apart (*SD = 1.37*). This follow-up period allowed sufficient time to observe potential changes in cognitive functioning, symptom progression or recovery, while also minimising the likelihood of excessive attrition from participants.

Participants from Assessment One were contacted via email and provided with a participant information sheet stating the details on the follow-up study. Those who wished to take part were booked into a one-to-one Zoom session with the researcher. During the Zoom session, consent was gained, and sub-tests of the BMIPB-II Form 2 were administered like for Assessment One. Following the session, participants received an email containing two links. The first was a Qualtrics based Covid-19 questionnaire designed to gather updated self-reported data on symptom severity, duration, impact on daily life, fatigue and quality of life. The second link provided access to the self-guided Word Categorisation and Recognition task, which participants were instructed to complete independently in their own time within a two week time period. Clear instructions were provided. Participants were contacted five to ten days after the Zoom assessment for the long-delay task aspects of the

BMIPB-II, the average delay was eight days (*SD = 4.41*). The data for this study was collected between October 2023 and January 2024.

Assessment Three

Participants were formally invited to take part in the third phase of the study. The procedure followed the same as the previous assessments. The long delay sub-test of the BMIPB-II was administered, between five and 22 days after the initial assessment, with an average of seven days (*SD=3.64*). As before, participants were not informed of the nature of the follow-up call, however they may have guessed the intention of this due to the previous follow-up calls. The data for this study were collected between December 2024 and March 2025.

Figure 7. All measurements and Assessment time points for all participants

Measure	pwLC			Self-guided task controls			Examiner task controls		
	A1	A2	A3	A1	A2	A3	A1	A2	A3
	N = 68	*N* = 46	*N* = 39	*N* = 55	*N* = 55	*N* = 55	*N* = 49	*N* = 49	*N* = 49
Covid survey (Acute & LC)	✓	✓	✓	x	x	x	x	x	x
Daily limitations	✓	✓	✓	x	x	x	x	x	x
Self- guided task	✓	✓	✓	✓	x	x	✓	x	x
Examiner-administered task	✓	✓	✓	✓	x	x	✓	x	x
Quality of life survey	✓	✓	✓	✓	x	x	✓	x	x
Fatigue survey	✓	✓	✓	✓	x	x	✓	x	x

Results: Characteristics

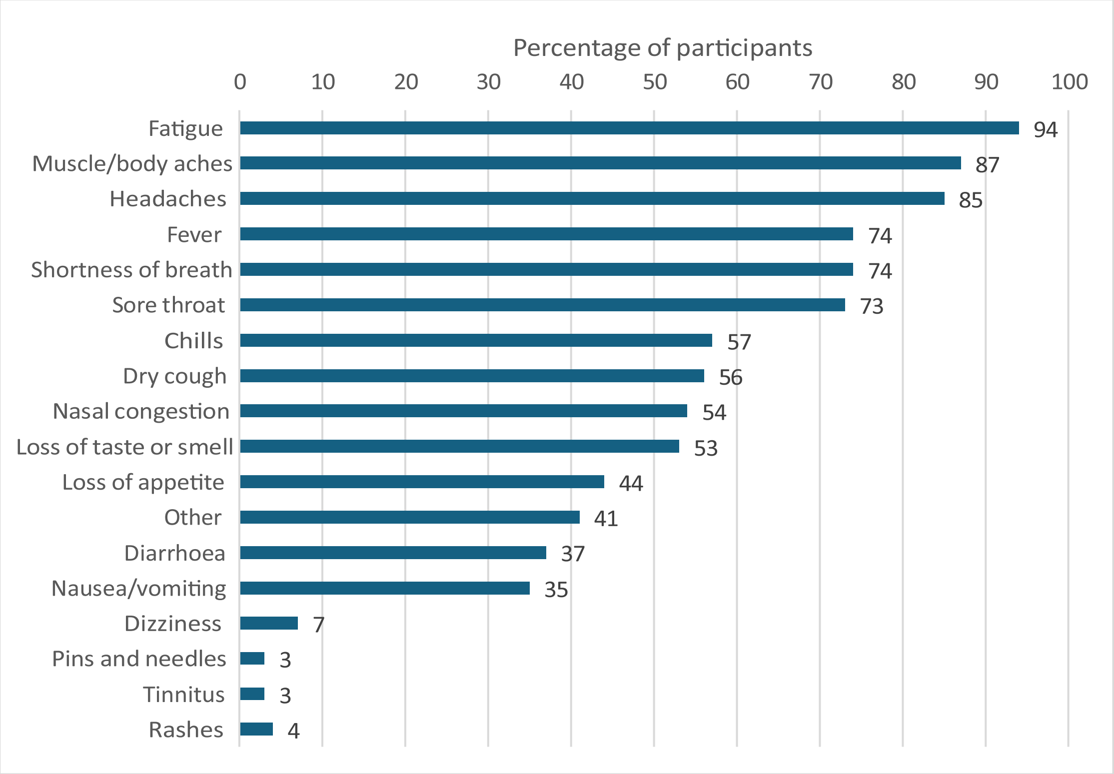
Statistical analyses were carried out using IBM SPSS Statistics (Version 27). All tests were two-tailed, and a *p*-value ≤ .05 was considered statistically significant.

Acute Infection Symptoms

At Assessment One, pwLC responded to questions regarding their acute Covid-19 infection, 62 people (91%) had the infection confirmed by a Covid test (Lateral flow test LFT or polymerase chain reaction test PCR) and six people (9%) suspected they had contracted Covid-19 but had not completed a LFT or PCR test to confirm this.

During the acute Covid-19 infection, six participants (9%) had self-reported mild symptoms, 55 participants (81%) self-reported they were quite ill but were able to recover at home, six participants (9%) were hospitalised but did not require ventilation and one participant (1%) was hospitalised and required ventilation. Thirty eight people (56%) had suffered with reinfection and 30 people (44%) had contracted Covid-19 only once. Furthermore, participants reported having between one and 14 symptoms during their acute infection, the average number of acute symptoms within the sample was 8.64 (*SD* = 3.14). Further details of symptoms reported during their infection can be seen in Figure 8.

Figure 8. Prevalence of self-reported acute Covid-19 symptoms at Assessment One

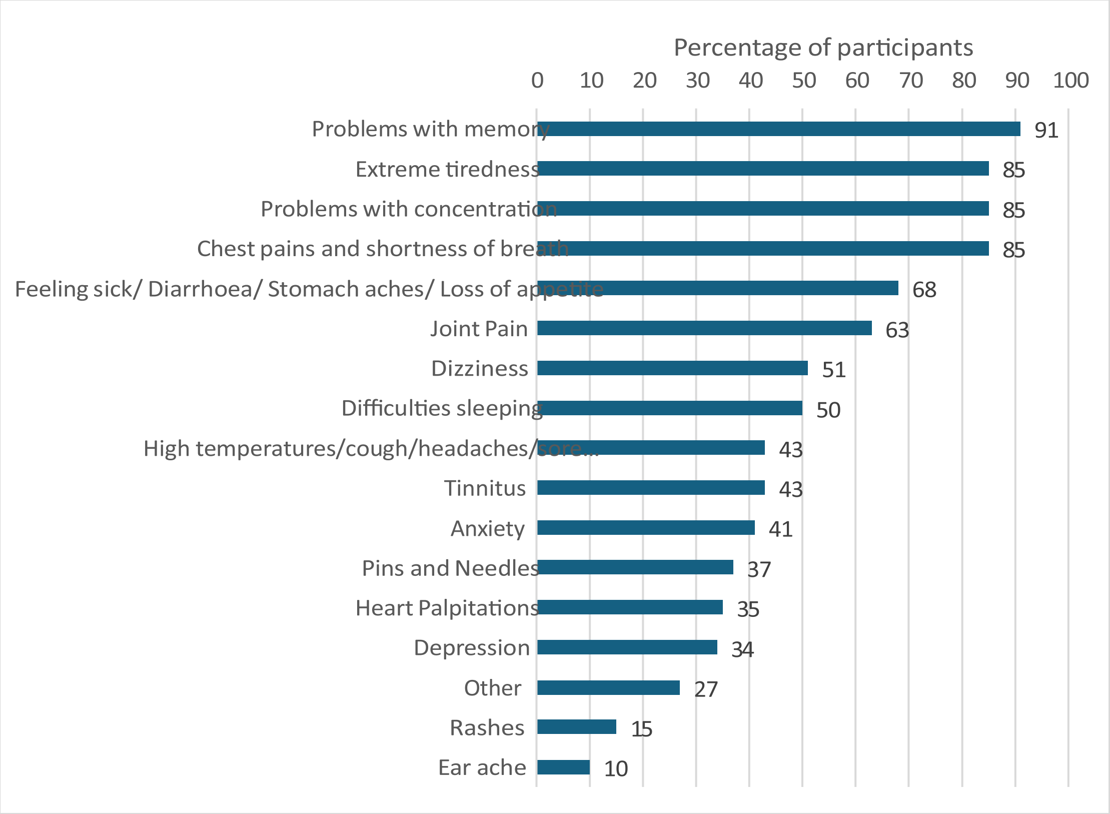


Other acute symptoms reported included cognitive issues such as brain fog, slow information processing, hallucinations, and word finding difficulties (*N* = 21); problems with blood pressure, heart rate, oxygen levels and excess sweating (*N* = 8), vertigo and dizziness (*N* = 5), organ pain (*N* = 4), blurred vision / changes to eyesight (*N* = 4), difficulties with speech and speech impediment (*N* = 3), involuntary shaking (*N* = 3), rashes / allergies / hay fever worsening (*N* = 3), sensitivity to light / noise / environment (*N* = 3), mood swings (*N* = 2), testicular pain or menstrual changes (*N* = 2), alopecia (*N* = 2), tinnitus (*N* = 2), pins and needles (*N* = 2), swollen fingers / toes (*N* = 2), insomnia (*N* = 2) extreme thirst (*N* = 1), weight gain (*N* = 1), arthritis (*N* = 1) and nose bleeds (*N* = 1).

Long Covid Symptoms

The amount of time living with LC ranged from five to forty-two months, with an average time of 22 months (*SD* = 9.34). All participants had LC symptoms lasting longer than three months. Out of 68 participants, 55 people (81%) had a formal LC diagnosis and 13 people (19%) suspected they had LC, but this had not been a confirmed diagnosis. Participants reported having between one and twenty-two long lasting symptoms as shown in Figure 9. The average across the sample was 10.8 symptoms (*SD* = 6.50).

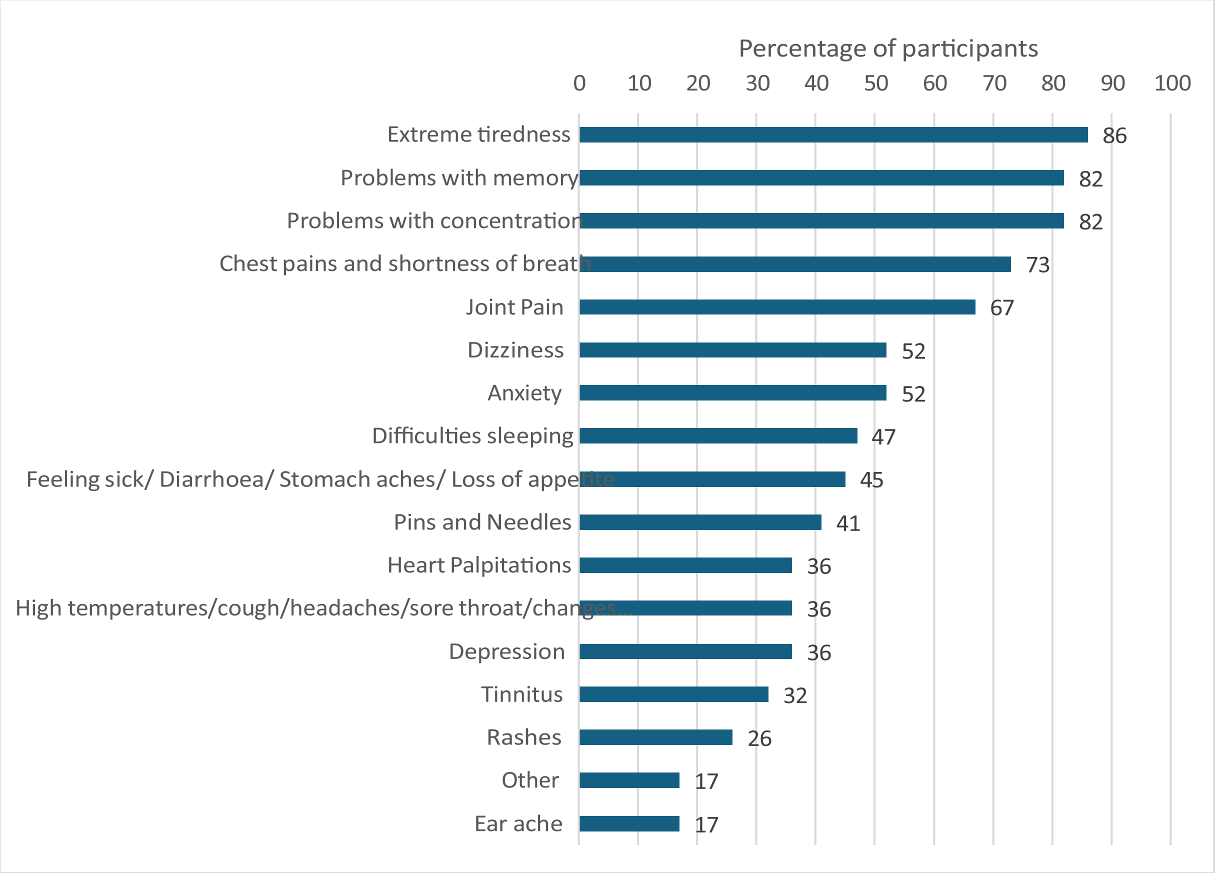
Figure 9. Prevalence of self-reported LC symptoms at Assessment One



Other long-lasting symptoms reported were sensitivity to light / noise / environment (*N* = 7), aching body/muscles (*N* = 7), blurred vision/changes to eyesight *(N* = 7), alopecia (*N* = 6), post-exertional malaise (*N* = 6), cognitive issues including brain fog, lack of information processing, hallucinations and word finding difficulties (*N* = 6), difficulties with speech or speech impediment (*N* = 5), problems with blood pressure, heart rate, oxygen levels and excess sweating (*N* = 4), vertigo and dizziness (*N* = 4), involuntary shaking (*N* = 4), worsening of rashes/allergies/hay fever (*N* = 4), gastrointestinal issues (*N* = 3), testicular pain or menstrual changes (*N* = 2), swollen fingers / toes (*N* = 1), insomnia (*N* = 2) weight gain (*N* = 1), nose bleeds (*N* = 1), incontinence (*N* = 1), reoccurring chest infection (*N* = 1) and blood pooling in extremities (*N* = 1).

Out of the sixty-eight participants from the first study, 68% participated in Assessment Two. Further information on participant attrition between assessments is shown in Figure 11. At Assessment Two, the amount of time living with LC ranged from 13 to 48 months, the average time was 31 months (*SD = 10.75*). The time since Assessment One was an average of 5.5 months (*SD* = 1.37). Out of 46 participants, 39 people (85%) had a formal diagnosis of LC and seven people (15%) suspected they had LC, but this had not been formally diagnosed. Participants were asked which symptoms they were still experiencing at the time of data collection and this resulted in them reporting having long lasting symptoms, which ranged between one and 17, the average across the sample was 9.24 (*SD = 5.09*) . These results are shown in Figure 10.

Figure 10. Prevalence of self-reported long lasting Long Covid symptoms at Assessment Two.



Other long-lasting symptoms reported were sensitivity to light/noise/environment (*N* = 1), low blood oxygen levels (*N* = 1), weight gain (*N* = 1), heavy limbs (*N* = 1), sweats (*N* = 1), menstrual changes (*N* = 1), PEM (*N* = 1) and blood pooling in extremities (*N* = 1). Participants were also asked to rank their symptoms in order of worst to best, the three symptoms ranked as the top three worse across the sample were extreme tiredness, memory problems and concentration problems.

Self-reported symptoms had reduced from between one and 24 (*M* = 14) at Assessment One to between one and 17 at Assessment Two (*M* = 9). The percentage of participants reporting cognitive symptoms had reduced, problems with memory were reported by 92% of participants (*N* = 62) at Assessment One compared to 82% (*N* = 38) at Assessment Two and problems with concentration were reported by 88% (*N* = 40) at Assessment One, compared to 82% of participants (*N* = 38) at Assessment Two.

Long Covid Strategies

Participants were asked whether they were currently using any devices, medication, or strategies to help with management of their LC symptoms. They were invited to provide free-text responses to this question. This question was not mandatory and as a result not all participants provided an answer. The responses and the number of participants using each is shown in Table 5.

Table 5. Self-reported techniques used by LC participants at Assessment Two

Techniques / Interventions for symptom management	**Number of participants (*N*, %)**
Prescribed medication from doctor	37 (80.4%)
Pacing (planning down time into routines)	14 (30.4%)
Yoga Nidra	7 (15.21%)
Vitamins and supplements	7 (15.21%)
Breathing exercises	6 (13.04%)
Over counter painkillers	5 (10.97%)
Mobility aids	5 (10.87%)

Long Covid clinic support	4 (8.69%)
Brain training	4 (8.69%)

Techniques / Interventions for symptom management	**Number of participants (*N*, %)**
Fitness watch	4 (8.69%)
Support from OT / SALT / Nutritionist	4 (8.69%)
“Visible” App	3 (6.52%)
Compression socks/gloves	3 (6.52%)
Use of blood pressure machine/oximeter	3 (6.52%)
High salt diet	3 (6.52%)
Oxygen therapy	2 (4.34%)
KiActiv- 1:1 mentoring for guided movement	2 (4.34%)
Self-help books	2 (4.34%)
Memory book	2 (4.34%)
Avoiding activities that cause distress	2 (4.34%)
Acupuncture	1 (2.17%)
Lymphatic drainage	1 (2.17%)
Mind mapping	1 (2.17%)
Vagas nerve stimulation	1 (2.17%)

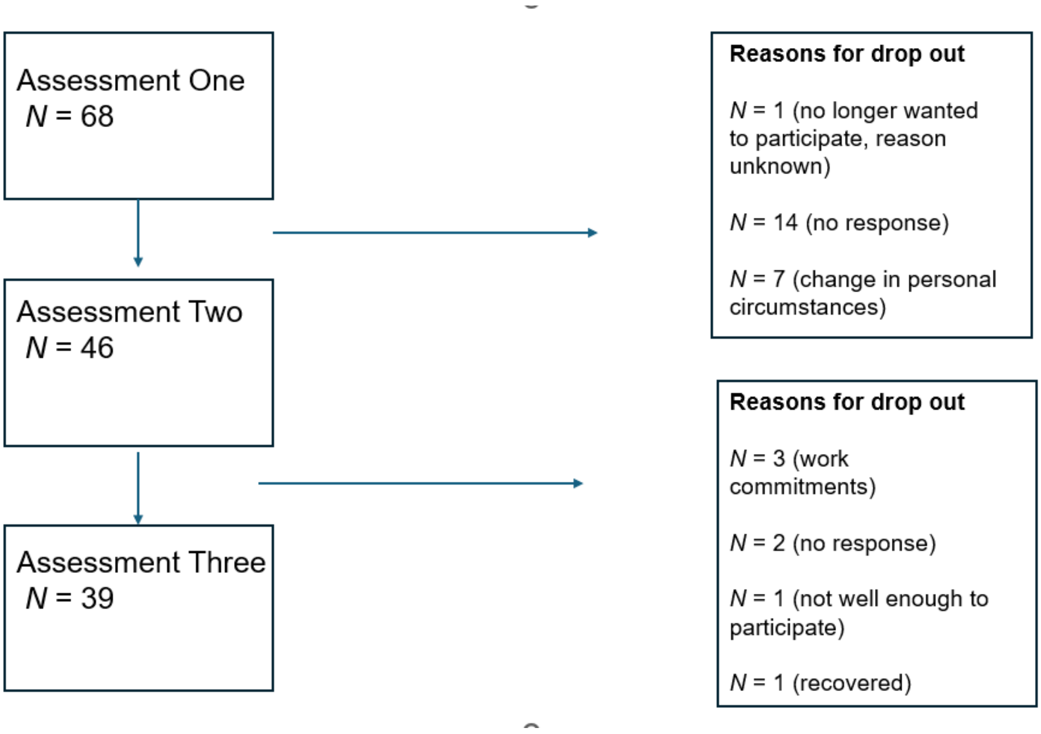
Self- Reported Ratings

Participants were asked to reflect and rate how they were feeling in themselves at the time of the study compared to the first study. Nineteen participants (41%) said they were feeling better than before, 15 participants (33%) said they felt the same and 12 participants (26%) said they felt worse than before. Participants were also asked to rate their ability to engage in work / social events compared to the first study. Fifteen participants (33%) were more able to engage in work and social events compared to before, 18 participants (39%) said there were no change, and 13 participants (28%) said their ability to engage in work and social events had deteriorated.

Participants were asked questions about how their symptoms had changed compared to Assessment One and if they had symptoms improvement or worsening. Thirty-four participants (74%) reported no worsening of symptoms. Twelve participants reported worsening of symptoms: problems with sleeping / tiredness ($N = 4$), memory problems ($N = 3$), joint pain ($N = 2$), depression ($N = 1$), feeling sick ($N = 1$), problems with concentration ($N = 1$). For participants who reported improvements in symptoms, the symptoms improved were ‘all symptoms’ ($N= 2$), heart palpitations ($N = 2$), problems with memory ($N = 2$), anxiety ($N = 1$), feeling sick ($N = 1$), joint pain ($N = 1$), shortness of breath ($N = 1$), tiredness ($N = 1$), other “able to do more” ($N = 1$).

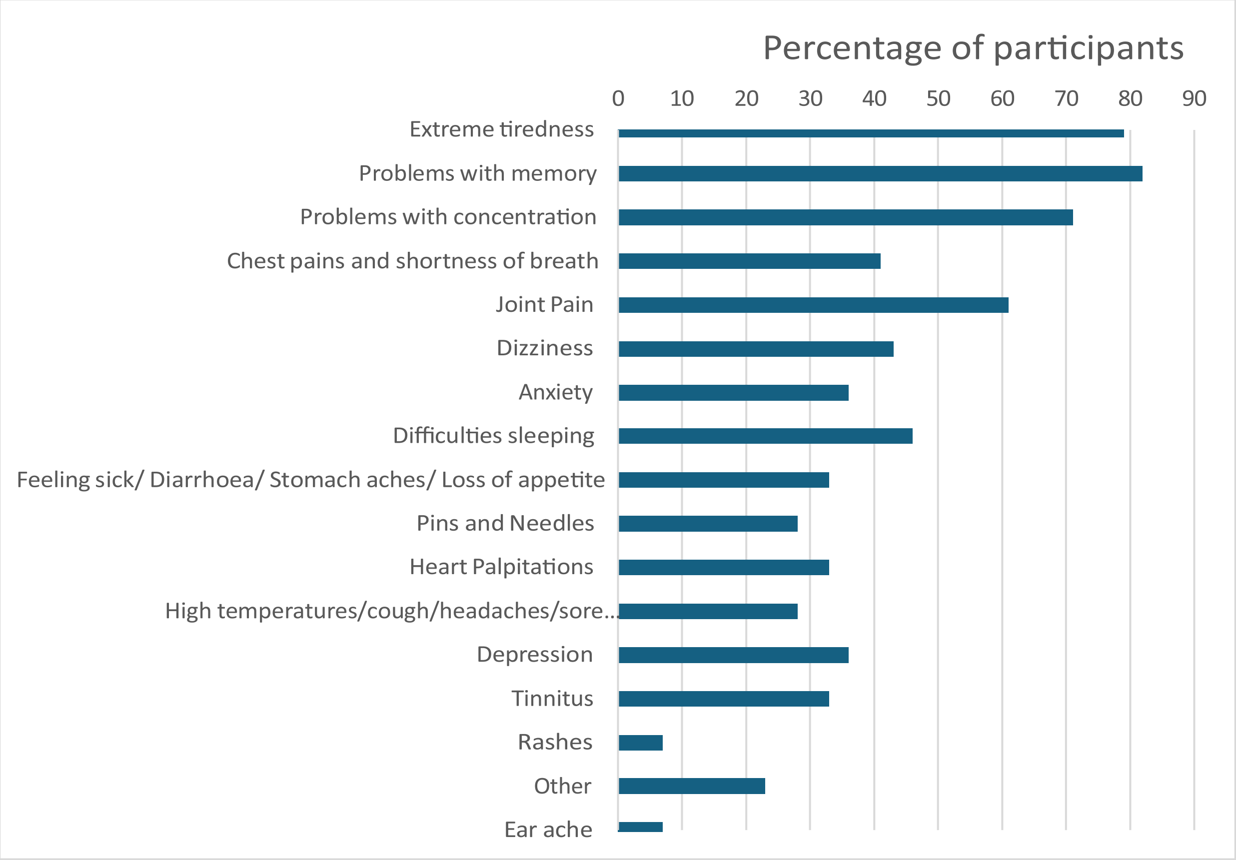
The time between the Assessment Two and Assessment Three ranged from 11 to 16 months, with an average of 13.7 months ($SD = 1.14$). Eighty four percent of participants who took part in Assessment One and in Assessment Two also participated in Assessment Three, demonstrating retention across timepoints which was 57.35% of the initial sample. The attrition rates and reasons for dropout are shown in Figure 11.

Figure 11. Attrition Rate



At Assessment Three, participants had been living with LC symptoms between 24 and 60 months, the average in the sample was 44 months (*SD = 11.79*). The participants self-reported between one and 34 symptoms, the average was 9.23 symptoms (*SD = 5.50*). The prevalence of different symptoms are shown in Figure 12. Extreme tiredness, problems with concentration and problems with memory continue to be the most prevalent and long-lasting symptoms.

Figure 12. Prevalence of self-reported LC symptoms at Assessment Three



Other LC symptoms included muscles weakness (*N* = 2), balance issues (*N* = 2), 'brain crashes' (*N* = 1), migraines (*N* = 1), increased need for sleep (*N* = 1), speech difficulties (*N* = 1) and twitching arms (*N* = 1).

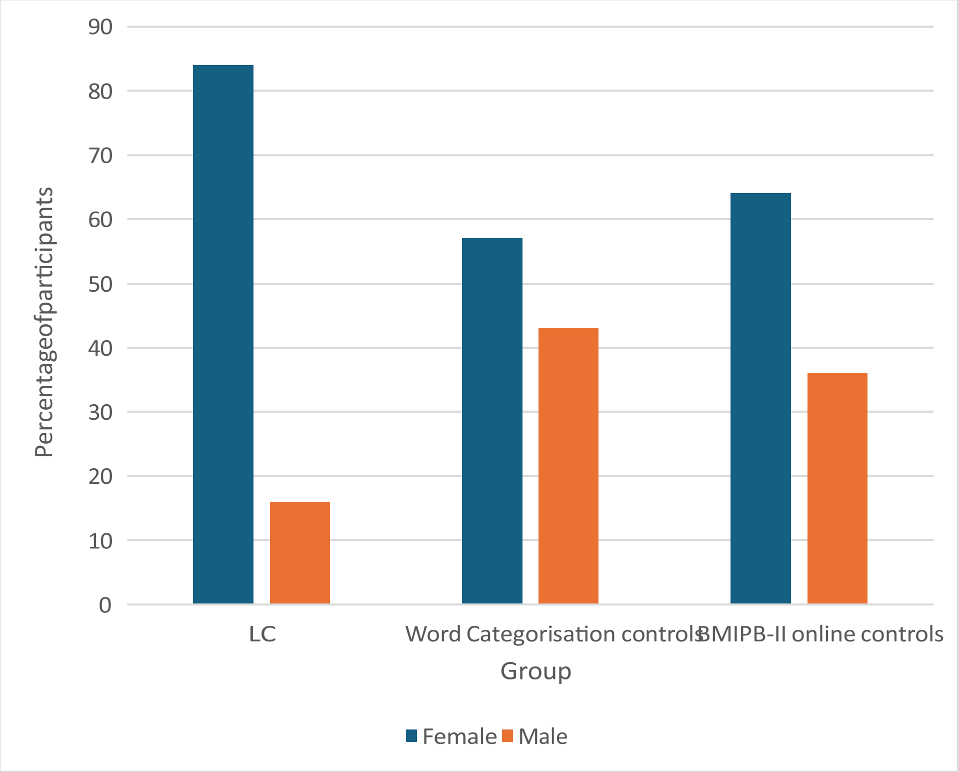
Participants were asked to reflect how they felt in themselves at the time of this study compared to how they felt at Assessment Two. Eight participants (21%) reported feeling the same, 20 participants (51%) reported feeling better and 11 (28%) participants reported feeling worse than before. Furthermore, participants were asked to disclose their ability to work or engage in social activities ‘now’ in comparison to the previous assessment. Thirteen participants (33.33%) reported feeling the same, 13 participants (33.33%) reported feeling better and 13 participants (33.33%) reported feeling worse than before.

Demographics- Comparison to Controls

At Assessment One, one-way between groups ANOVAs were used to explore any differences between the groups of participants (pwLC, self-guided Word Categorisation and Recognition controls and BMIPB-II controls), the demographics are displayed in Table 6. The ANOVAs showed there was no significant difference between ages in the groups (*F* (2, 171) = .045, *p* = .956). However, there was a significant difference between groups for level of education (*F* (2,171) = 5.155, *p* = .007). A post-hoc LSD test indicated that the level of education was significantly higher for the self-guided Word Categorisation and Recognition task controls compared to the pwLC (*p* = .002, 95% CI [.71, 3.16]) and between pwLC and BMIPB-II controls (*p* = .043, 95% CI [-2.57, .04]). There were no significant differences between the online controls and the BMIPB-II controls (*p* = .349, CI [-.70, 1.96]).

For categorical outcome (sex), chi-square tests of independence were performed to evaluate whether there were differences in sex distribution between groups. This was significant (χ^2 ((2), *N* = 172) = 11.052, *p* = .004). The distribution between sexes is not the same across groups, as shown in Figure 13.

Figure 13. Sex differences in each group at Assessment One



At Assessment Two, the same one-way between groups ANOVAs were used to explore any differences between the groups of participants (pwLC, self-guided Word Categorisation and Recognition task controls and BMIPB-II controls) and although the LC group was smaller at Assessment Two, the results remained the same as Assessments One (no significant difference between ages in the groups (*F* (2, 149) = .208, *p* = .813) and a significant difference between groups for levels of education (*F* (2,149) = 3.992, *p* = .021). The same chi-square test of independence was performed. The difference between groups for sex remained (χ^2 (2, *N* = 150) = 6.15, *p* = .046).

The same between-groups ANOVAs were conducted at Assessment Three. Despite the LC sample reducing, the results were the same (no significant differences between ages in the groups, (*F* (2, 142) = .276, *p* = .765) and a significant difference between groups for levels of education (*F* (2,142) = 3.728, *p* = .026). The difference between groups for sex was no longer significant (χ^2 (2), *N* = 143) = 4.988, *p* = .083).

Fatigue and Quality of life

Fatigue was assessed using the Chalder Fatigue Questionnaire (CFQ; Cella & Chalder, 2010). The maximum score for the questionnaire is 33. Higher scores indicate higher levels of fatigue. Mean scores and standard deviations for pwLC are presented in Table 6.

Table 6. Mean fatigue scores across Assessments

Assessment One **M (*SD*)**	**Assessment Two** **M (*SD*)**	**Assessment Three** **M (*SD*)**
22.74 (10.70)	26.32 (5.67)	24.61 (7.60)

A repeated-measures ANOVA was used to determine change in fatigue levels over time for the participants who took part in all three Assessments. The results determined that fatigue scores remained stable across the three time points (*F* (1.416) = 1.989, *p* = .159), suggesting that fatigue levels did not significantly improve nor deteriorate.

PwLC had significantly higher scores on fatigue compared to controls at all assessments (Assessment One: (*t* (115) = -6.828, *p* = <.001, *r* = .054). Assessment Two: *(t* (93) = -13.09, *p* = <.001, *r* = .081) and Assessment Three (*t* (92) = -10.15, *p* = <.001, r = 0.73).

Quality of life was measured using the Quality of Life scale (QOLS; Flanagan, 1978). The maximum score for the scale is 112. Higher scores indicate better perceived quality of life. Mean scores and standard deviations for pwLC are displayed in Table 7.

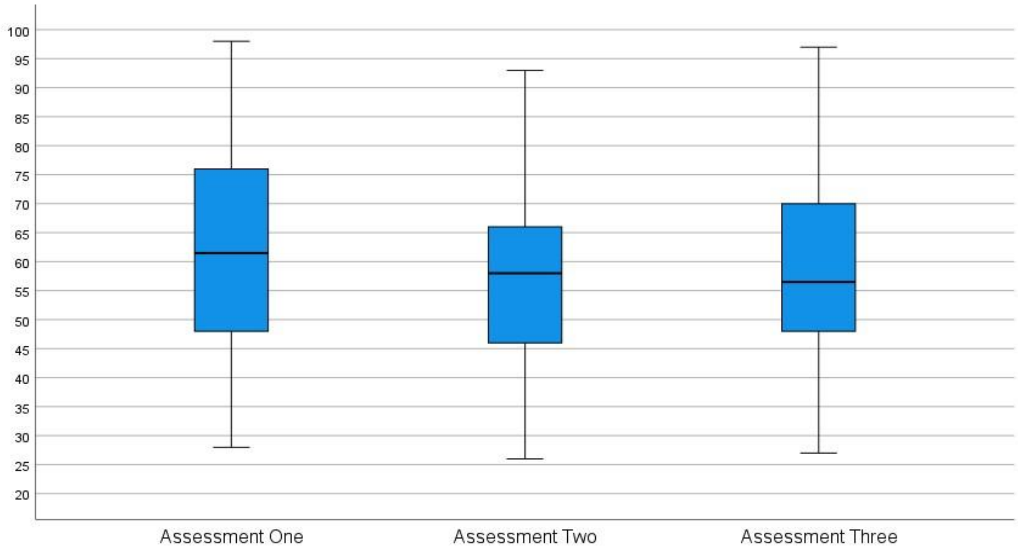
Table 7. Mean QoL scores across Assessments

Assessment One **M (*SD)***	**Assessment Two** **M (*SD)***	**Assessment Three** **M (*SD)***
62.45 (18.36)	56.42 (15.08)	59.21 (17.91)

PwLC also had significantly lower scores on the QoL scale compared to healthy controls at all Assessments (Assessment One: (*t* (115) = 6.103, *p* = <.001, r = .050). Assessment Two, *(t* (93) = 8.22*, p* = <.001, r = .065) and Assessment Three (*t* (92) = 7.97, *p* = <.001, r = .064).

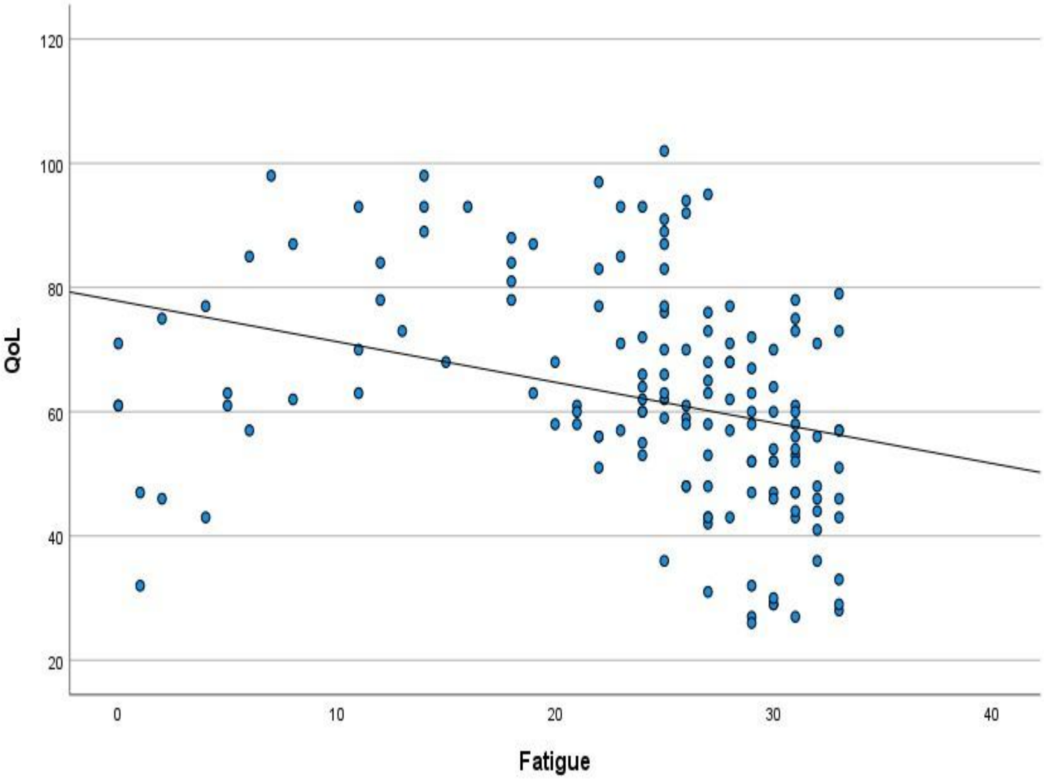
A repeated-measures ANOVA determined that QoL scores differed significantly across three time points for the participants who completed all assessments (*F* (2, 39) = 4.193, *p* = .019, ηp² = .18). Post hoc pairwise comparisons using Bonferroni correction showed a statistically significant decrease in QoL score between Assessment One and Assessment Two (*p* = .034) and no difference between Assessment Two and the Assessment Three (*p* = .318). This indicates that QoL scores reduced at Assessment Two and remained lower at Assessment Three, in comparison to Assessment One, as illustrated in Figure 14.

Figure 14. Boxplot of QoL scores across Assessments.



Pearsons's correlations were performed to assess the relationship between fatigue and QoL scores. There was a negative correlation between the variables (*r* = .317, *p* = < . 001) suggesting that increased fatigue is associated with reduced QoL, shown in Figure 15.

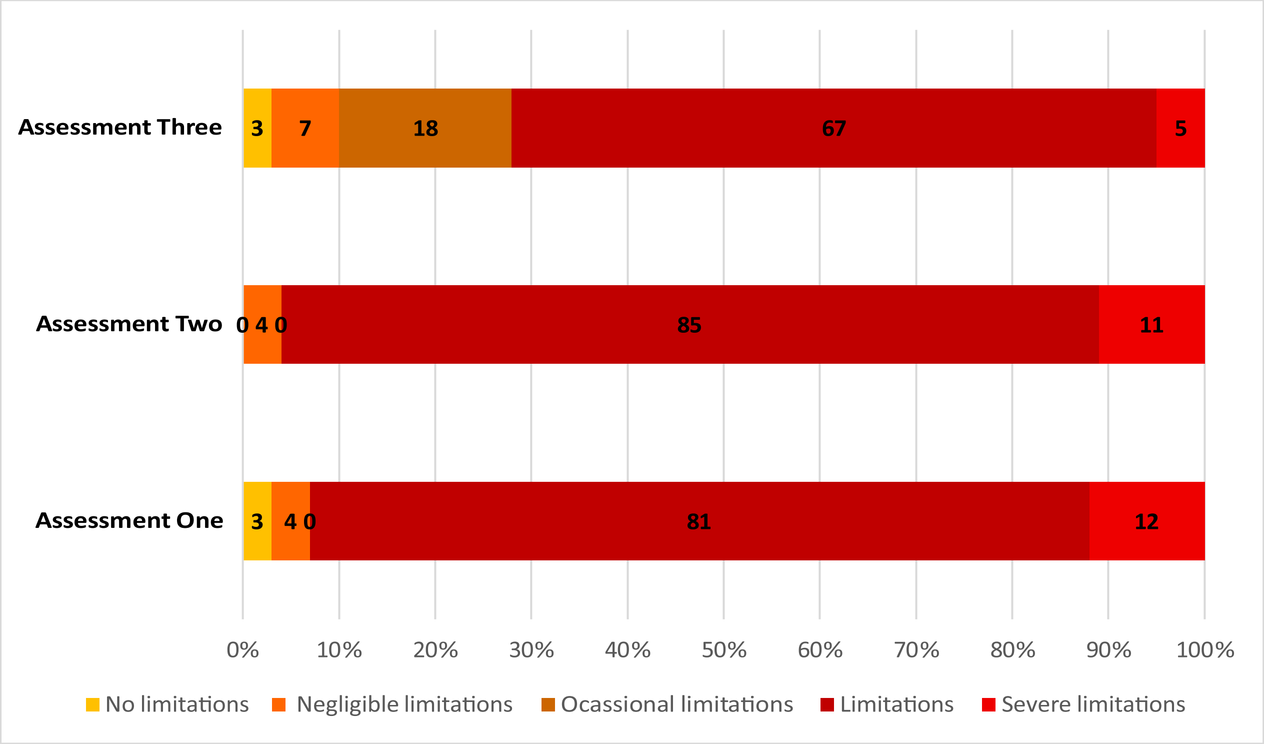
Figure 15. Scatterplot illustrating the negative correlation between QoL and fatigue for pwLC.



Daily Limitations and Severity

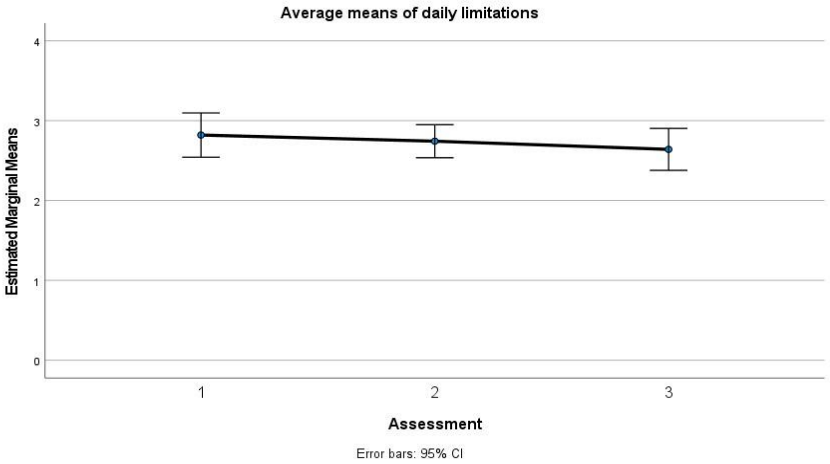
The effects of LC on daily limitations were self-reported at all assessments and the results are shown in Figure 16.

Figure 16. Limitations across Assessments



For participants who completed all three assessments (*N* = 39), the average score for limitations was 2.82 (*SD* = 0.84) at Assessment One, 2.74 (*SD* = 0.63) at Assessment Two and 2.64 (*SD* = 0.81) at Assessment Three (scoring detailed in Table 7), suggesting a gradual reduction in limitations, which is illustrated in Figure 17.

Figure 17. Average daily limitations across Assessments.



Acute Covid-19 Severity Index (ASI)

The ASI scores for participants at each Assessment are shown in Table 8. The ASI score was only collected from participants at Assessment One.

Table 8. Acute-19 Severity Index Scores

Assessment	**Minimum score**	**Maximum score**	**M (SD)**
One	3	18	10.67 (3.24)
Two	3	17	10.76 (3.38)
Three	3	18	12.66 (3.19)

Pearsons's correlations were performed to explore the relationships between ASI and other variables (daily limitations, fatigue, QoL and LC severity) at Assessment

One. There were positive correlations between ASI and daily limitations (*r* = .231, *p* = .004), LCSI (*r* = .313, *p* < .001) suggesting that a more severe acute Covid-19 infection was associated with greater daily limitations and higher LCSI scores. There was no correlation between ASI and QoL (*r* = –.213, *p* = .008) nor between ASI and fatigue (*r* = .023, *p* = .776). There were positive correlations between LCSI and QoL (*r* = .400, *p* = <.001) suggesting that pwLC with higher LCSI scores are associated with lower QoL and had more severe ASI. LCSI did not correlate with daily limitations (*r* = .157, *p* = .053) nor fatigue (*r* = .224, *p* = .006).

Long Covid Severity Index (LCSI)

The LCSI scores for each Assessment are shown in Table 9.

Table 9. LC Severity Index Scores

Assessment	**Minimum score**	**Maximum score**	**M (SD)**
One	14	68	38.63 (13.79)
Two	23	73	46.10 (12.69)
Three	30	76	56.07 (13.39)

Results: Cognitive Performance on The Examiner Administered Task

Assessment One

The percentile for each raw score on the BMIPB-II sub-tests was extracted from the manual for aged matched normative data held for the BMIPB-II. One sample t-tests were performed on raw scores to compare performance of pwLC with the overall aged matched normative results (45-59) from the BMIPB-II. For all measures, pwLC had significantly poorer cognitive performance (lower scores) compared to the aged matched norm as shown in Table 10.

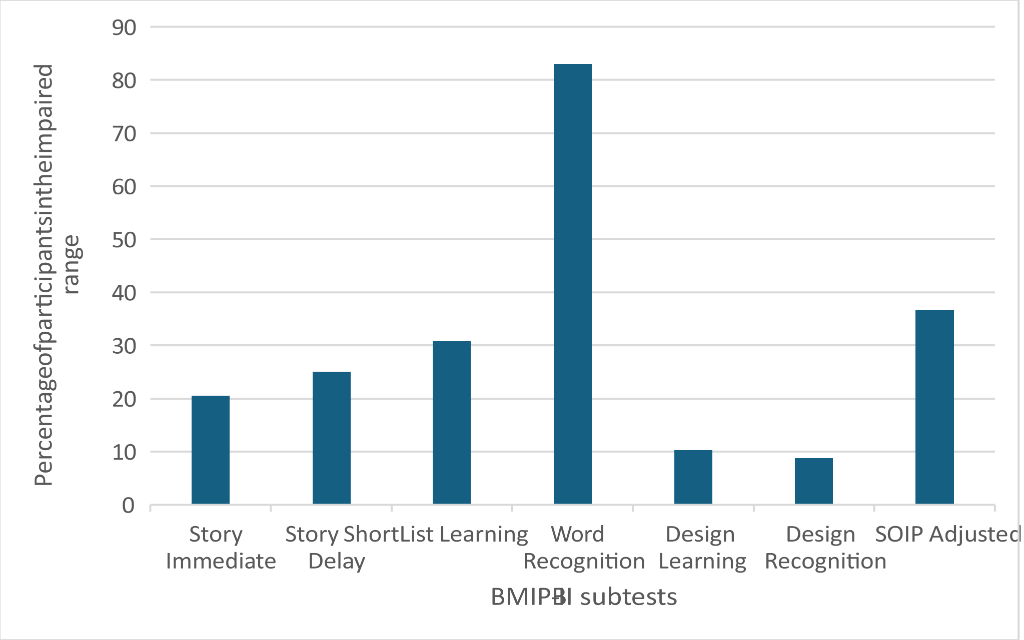
Table 10. Comparison of performance between pwLC and normative samples on sub-tests of the BMIPB-II at Assessment One

Sub-Test of the BMIPB-II	**Sample**	**Normative M**	**Cohen's**	***t*-value**	
	M (*SD*)	**M (*SD*)**	***d***		**(*p*-value)**
Story Recall Immediate	19.76 (9.01)	31 (9.13)	1.22	-7.94	< .001
Story Recall Short Delay	17.23 (9.78)	28 (8.75)	1.08	-7.15	< .001
List Learning	40.93 (9.62)	55 (8.67)	1.51	-.9.93	< .001
Word Recognition (item)	18.82 (5.49)	28 (1.56)	2.29	-16.62	< .001
Word Recognition (source)	17.73 (6.07)	28 (2.81)	2.17	15.30	< .001
Design Learning	33.65 (10.82)	40 (9.69)	0.62	5.39	< .001
Design Recognition (item)	34.31 (6.28)	36(3.96)	0.32	-2.20	< .050
Design Recognition (source)	7.13 (2.23)	8(2.35)	0.37	2.24	< .001
Speed of information processing	48.75 (20.11)	69 (13)	1.19	-8.16	< .001

Further analyses were carried out on the Word Recognition tasks to investigate the possibility that the observed results were due to poor effort / performance validity at the time of testing driven by factors such as fatigue, poor engagement. This involved exploring whether the results of the word recognition task were above chance. Compared to the average of 28 out of 30 for the normative data (93%), the average accuracy of word recognition in pwLC was 18 out of 30 (63%) and only 73% scored above chance. This suggest that 27% of participants were no better than guessing. The average source memory (correct recall of whether the target word belonged to List A or List B) was 17 out of 30 (59%), with 66% of participants scoring above chance. This suggests that a third of participants performed below chance level. This demonstrates pwLC have impaired recognition and source memory compared to the normative data.

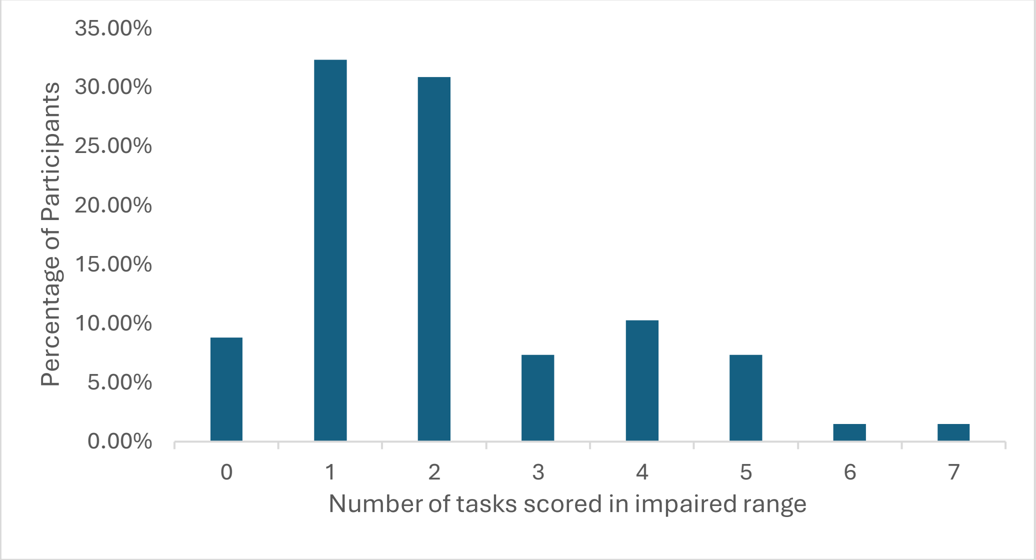
Impairment, defined as scores below 2nd percentile rank with reference to the normative sample (Lezak, 2004) was evident across all measures of the BMIPB-II but was not the case for all people with LC as shown in Figure 18.

Figure 18. Prevalence of scores in the impaired range by BMIPB-II task at Assessment One



To further explore the degree of impairment for pwLC across the different tasks, data were coded for whether impairment was present or not, and the total number of scores in the impaired range per participant was calculated (Figure 19). It was found that 91% percent of participants demonstrated impairment in one or more tasks. However, by definition, an impairment would be expected whereby even 2% of healthy controls would underperform in any one task. It can be seen that 58.81% of pwLC had two or more impairments and 27.93% had three or more impairments, which is more than would be expected in a healthy sample.

Figure 19. Bar chart of number of task impairment at Assessment One



Although impaired performance was observed across all measures, the largest percentage of participants in the impaired range was for the Word Recognition task (83%). This high prevalence raised further questions. Was this reflective of LC or could this be due to the differences in the way that the assessment was completed (online; test material presented via an audio recording) compared to the normative sample (face-to-face; test materials were read out by the examiner)? With the aim of testing healthy controls in the same format as that used while testing pwLC (online) and to explore whether the poor performance observed could have been due to the online administration, a small sample of healthy participants was recruited.

Supplementary BMIPB-II comparison: Online performance by healthy controls on the List Learning and Word Recognition tasks (these tasks are connected to one another).

Forty-nine control participants took part in this study. Participants, who were recruited on social media were matched as closely as possible to the LC participants for age (M = 45.10, SD = 13.58) and sex (57% female). The participants confirmed they did not have a diagnosis of, nor suspected LC. There were no other exclusion criteria. The control group scored significantly better than the LC participants in the selected tasks. The mode of test administration was the same as for the pwLC.

Table 11. Comparison of performance between pwLC and controls on the online administration of the BMIPB-II at Assessment One

Sub-Test	**pwLC M (SD) N = 64**	**Control M (SD) N = 49**	**Cohen's *d***	***t*-value**	**Significance (*p*-value)**
List Learning	41.07 (9.74)	47.36 (9.57)	0.65	3.428	< .001
Word Recognition (item)	18.82 (5.45)	24.87 (3.41)	1.33	6.813	< .001
Word Recognition (source)	17.58 (6.13)	23.28 (4.18)	1.08	5.587	< .001

Although the controls performed better than pwLC, and the prevalence of impairments on those tasks was lower for the control group (List Learning controls: 12.24% vs. pwLC 30.88%, Word Recognition (item) controls: 42.86% vs. pwLC 83.82%, Word Recognition (source) controls: 14.29% vs. pwLC 45.59%), they also scored significantly lower than the normative sample on those tasks (see Table 12). This suggests that the modification to the way that these tasks were administered may have contributed to the results to a certain extent, but is unlikely to account for all the increases in impairment seen in pwLC.

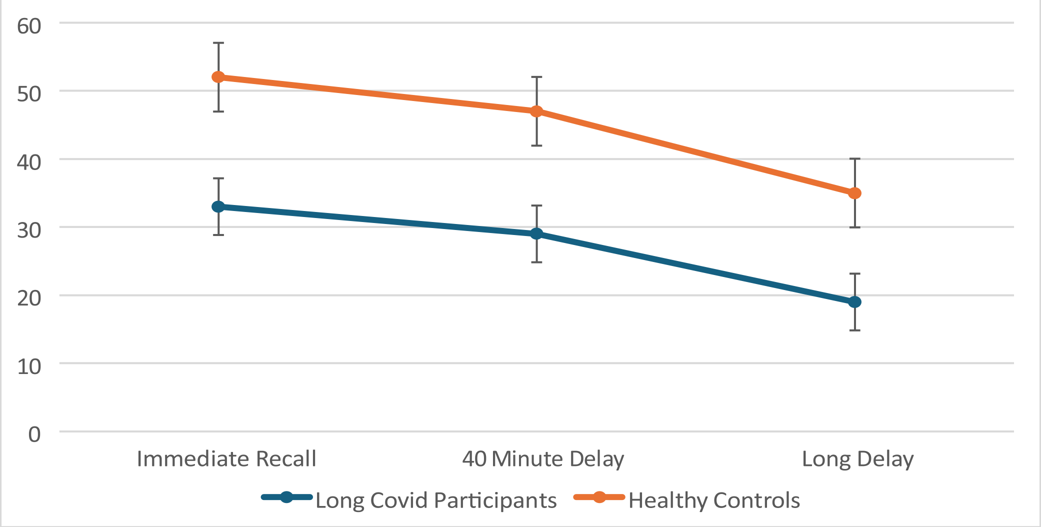
Table 12. Comparison of performance between the control sample and the normative data at Assessment One.

Sub-Test	**Control** ***M* (*SD*)** ***N* = 49**	**Normative** ***M* (*SD*)** ***N* = 110**	**Cohen's *d***	***t* value**	**Significance** **(*p*-value)**
List Learning	47.36 *(9.57)*	55 (*8.67)*	0.83	-4.967	< .001
Word recognition (item)	24.87 *(3.41)*	28 *(1.56)*	1.18	-7.958	< .001
Word Recognition (source)	23.28 *(4.18)*	28 *(2.81)*	1.32	-8.353	< .001

The long-delay tasks intend to measure forgetting and long-term memory consolidation. For the Story Recall and List Learning long delay tasks, the percentage of the information retained over time was investigated by comparing performance between pwLC and the age-matched controls immediately after presentation, after a short-delay (30-40 minutes) and after a long-delay (one week).

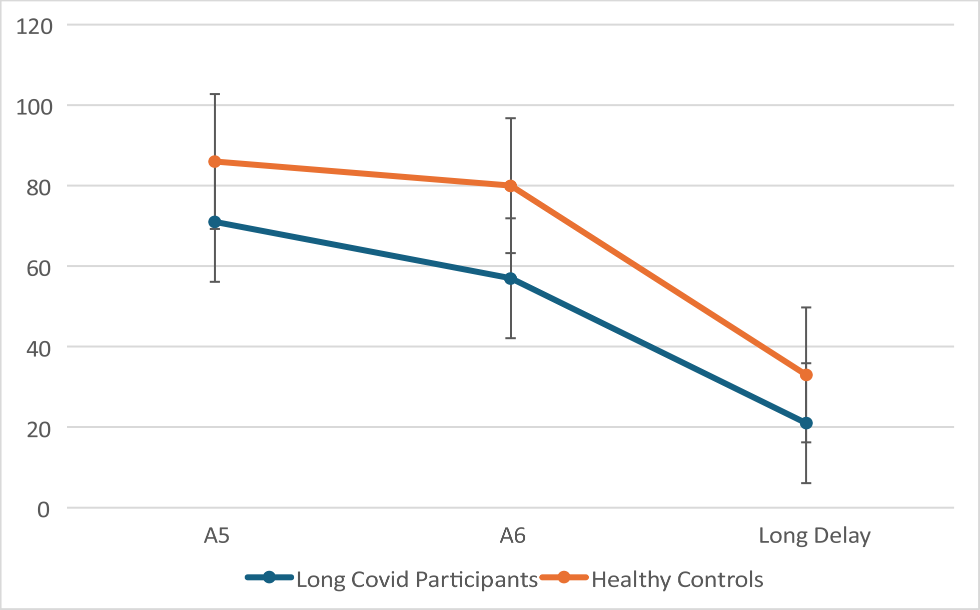
For Story Recall, this showed that the information retained was significantly below the normative sample at all testing intervals as shown in Figure 20, Immediate Recall (*t* (68) =8.47, *p* = < .001, *r* = .72), Short Delay Recall (t (68) = 7.75, *p* = < .001, *r* = .69) and Long Delay (t (68) = 7.04, *p*= < .001, *r* = .65).

Figure 20. Percentage of information retained on story recall at different points in time at Assessment One



For List Learning, information retained at all three points of time was also significantly lower in pwLC comparatively to the normative sample at Immediate Recall (A5) (*t* (67) = 6.51, *p* = < .001, *r* = .62), Interference (A6) (*t* (67) = 8.19, *p* = < .001, *r* = .71) and Long Delay (*t* (67) = 3.69, *p* = .003, *r* = .41) as shown in Figure 21.

Figure 21. List information recall at different points in time at Assessment One

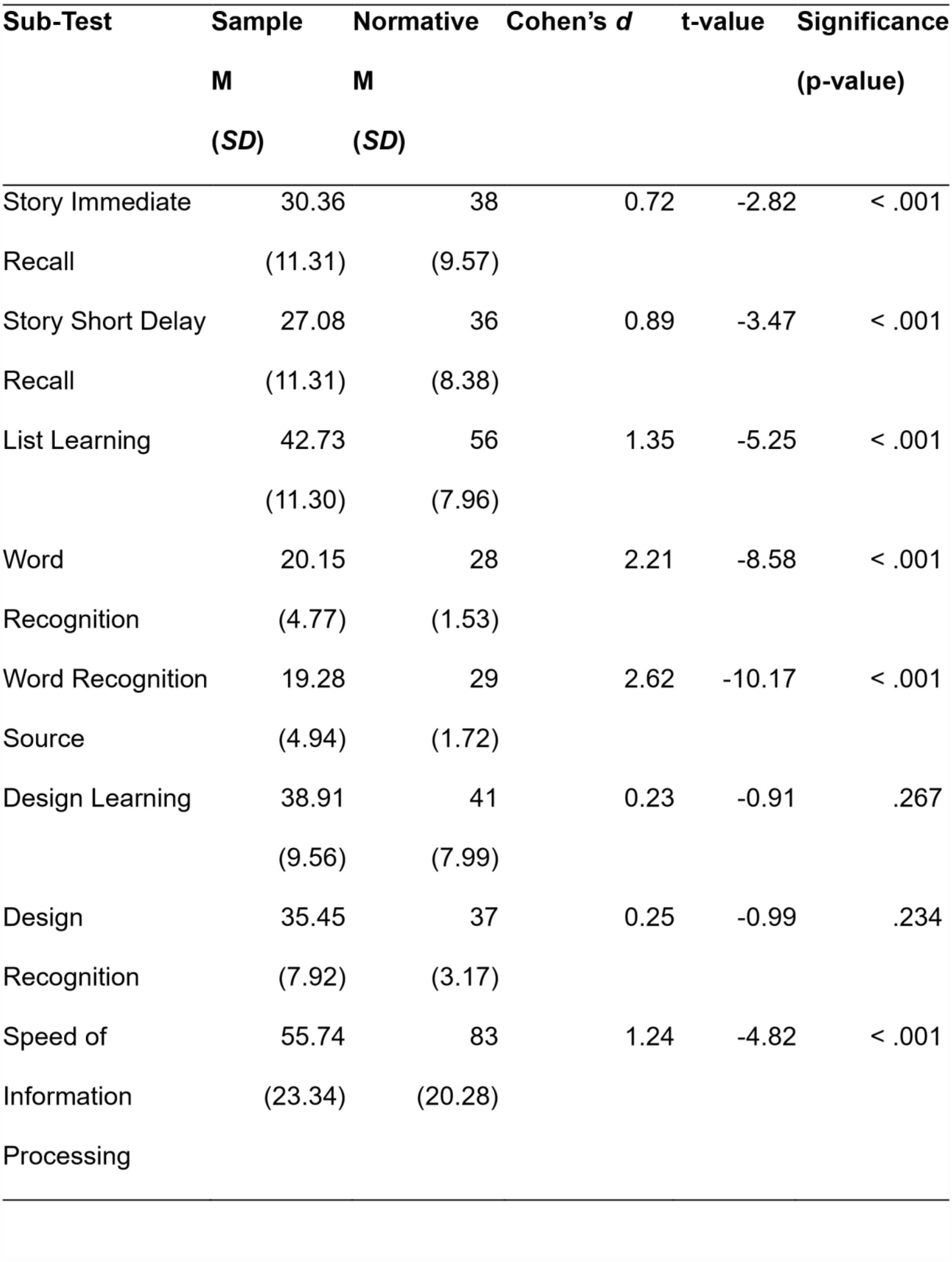


Pearson correlation coefficient was computed to assess relationships between LCSI scores and other variables. There was no significant relationship between LSCI and number of impaired tasks (*r* =.311, *p* =.010). When assessing relationships between LCSI and raw scores on the BMIPB-II subtests, there were no relationships between LSCI and any of the tasks. Pearsons's correlations were also computed to assess relationships between ASI and performance. The only correlation was between ASI and SOIP (*r* = -.249, *p* = .041).

Assessment Two

One sample t-tests were performed to compare performance of pwLC with aged matched normative results on the BMIPB-II (Table 13). PwLC scored significantly poorer (lower raw scores) than the normative sample across all domains with the exception of Design Learning and Design Recognition sub-tests.

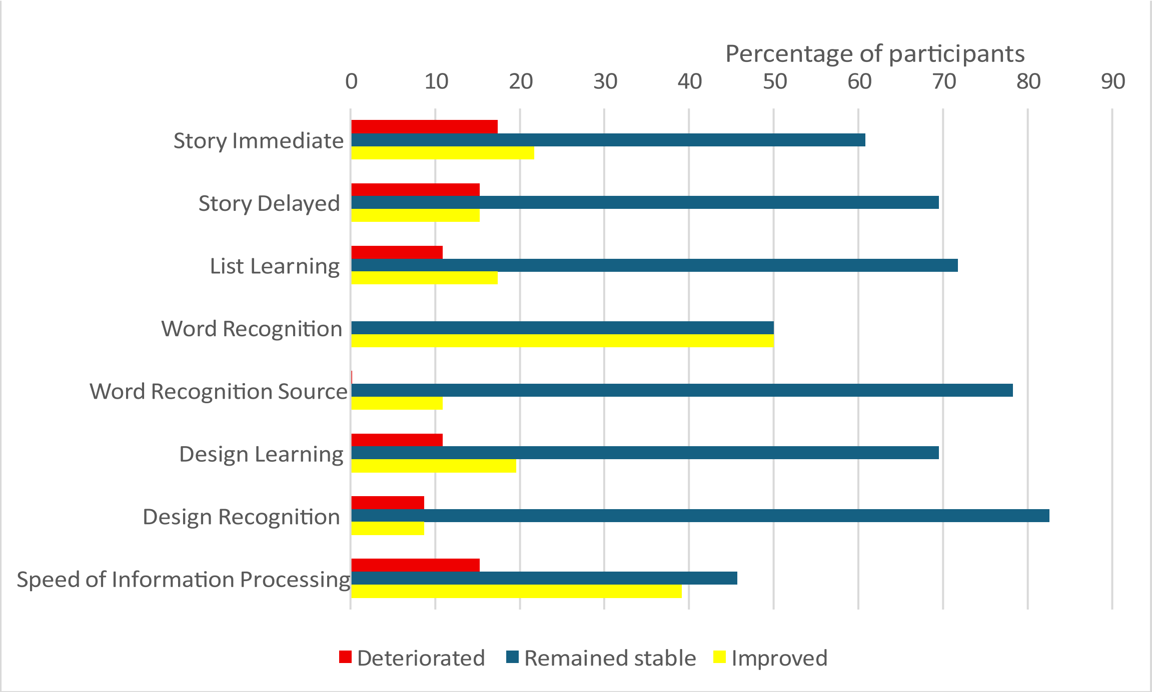
Table 13. Comparison of performance between the LC and normative samples on sub-tests of the BMIPB-II at Assessment Two



Sub-Test	**Sample M (*SD*)**	**Normative M (*SD*)**	**Cohen's *d***	**t-value**	**Significance (p-value)**
Story Immediate Recall	30.36 (11.31)	38 (9.57)	0.72	-2.82	< .001
Story Short Delay Recall	27.08 (11.31)	36 (8.38)	0.89	-3.47	< .001
List Learning	42.73 (11.30)	56 (7.96)	1.35	-5.25	< .001
Word Recognition	20.15 (4.77)	28 (1.53)	2.21	-8.58	< .001
Word Recognition Source	19.28 (4.94)	29 (1.72)	2.62	-10.17	< .001
Design Learning	38.91 (9.56)	41 (7.99)	0.23	-0.91	.267
Design Recognition	35.45 (7.92)	37 (3.17)	0.25	-0.99	.234
Speed of Information Processing	55.74 (23.34)	83 (20.28)	1.24	-4.82	< .001

Furthermore, T-scores for change were calculated to explore the extent of changes in performance within participants with reference to change to the normative sample. Differences in scores were calculated by converting raw scores at the two assessments into z- scores which were then transformed into T-scores to facilitate interpretation. A score below 40 indicates deterioration, a score between 40 and 60 suggests stability in performance and a score of above 60 indicates improved performance. The results are shown in Figure 22.

Figure 22. Distribution of scores for change between Assessment One and Assessment Two



The task where the largest proportion of participant showed improvement was Word Recognition; however, this was the most impaired at Assessment One, thus this does not mean that performance reached average levels at the second assessment, as despite significantly better scores for half the sample, the overall average was still low compared to the normative sample.

Impairment across sub-tests was explored. Four participants (9%) did not have impairment in any of the sub-tests, while 16 participants (35%) had impairment on one task and 13 participants (28%) had impairment on two tasks. Four participants (9%) had three impaired tasks; another four participants (9%) on four tasks and four participants (9%) were impaired on five tasks. One participant had impairments across all seven tasks. As expected and consistent with the results from Assessment One, the sub-test where most people scored within the impairment range Word Recognition.

Next, pwLC's performance was compared to healthy controls recruited for this study on the Word Recognition and List Learning tasks. Consistent with the results in Assessment One, pwLC performed significantly poorer than controls as shown in Table 14.

Table 14. Comparison of performance between pwLC and controls on the online administration of the BMIPB-II at Assessment Two

Sub-Test	**pwLC M (*SD*) N = 46**	**Control M (*SD*) N = 49**	**Cohen's *d***	***t*-value**	**Significance (*p*-value)**
List Learning	42.74 (11.30)	47.36 (9.57)	0.44	2.14	.033
Word Recognition	19.28 (4.94)	24.87 (3.41)	1.31	5.82	< .001
Word Recognition Source	20.15 (4.77)	23.28 (4.18)	0.69	3.40	< .001

Further analyses explored the rate of forgetting in the Long Delay tasks. For the Story Recall and List Learning at all intervals, the percentage of the information retained over time was investigated by comparing performance between pwLC and the age-matched normative data. Figures 23 and 24 show the information retention at three points in time for Story Recall and List Learning. The results do not show any signs of accelerated forgetting as performance at long-delay is not disproportionately lower.

Figure 23. Information retention of three points in time for Story Recall at Assessment Two

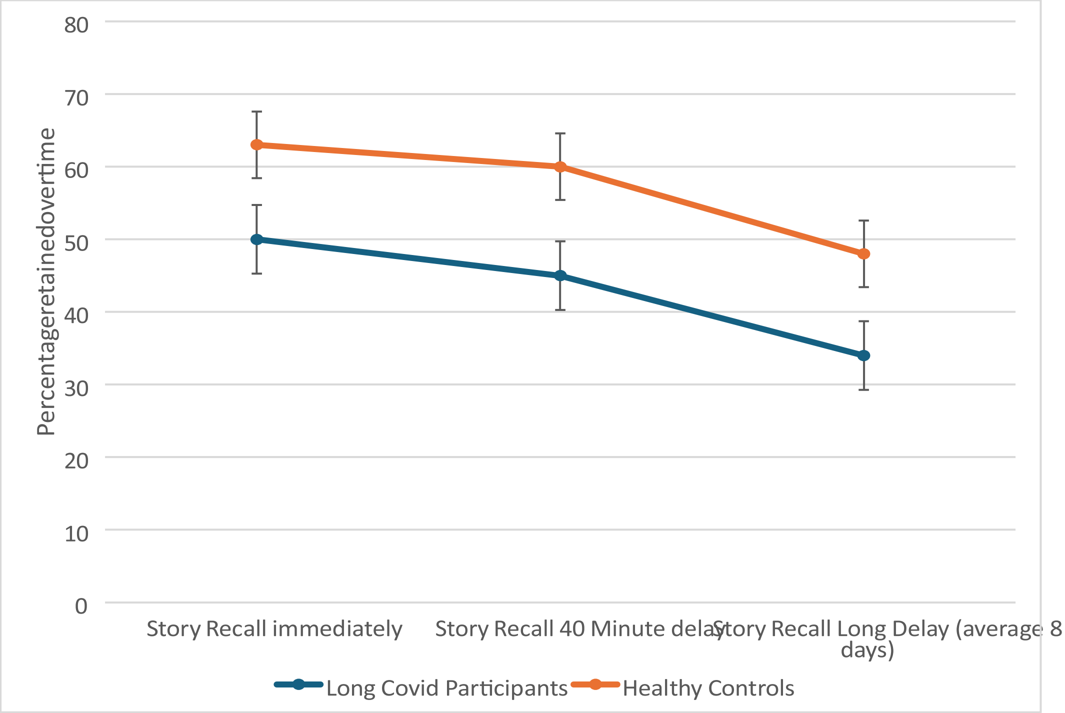
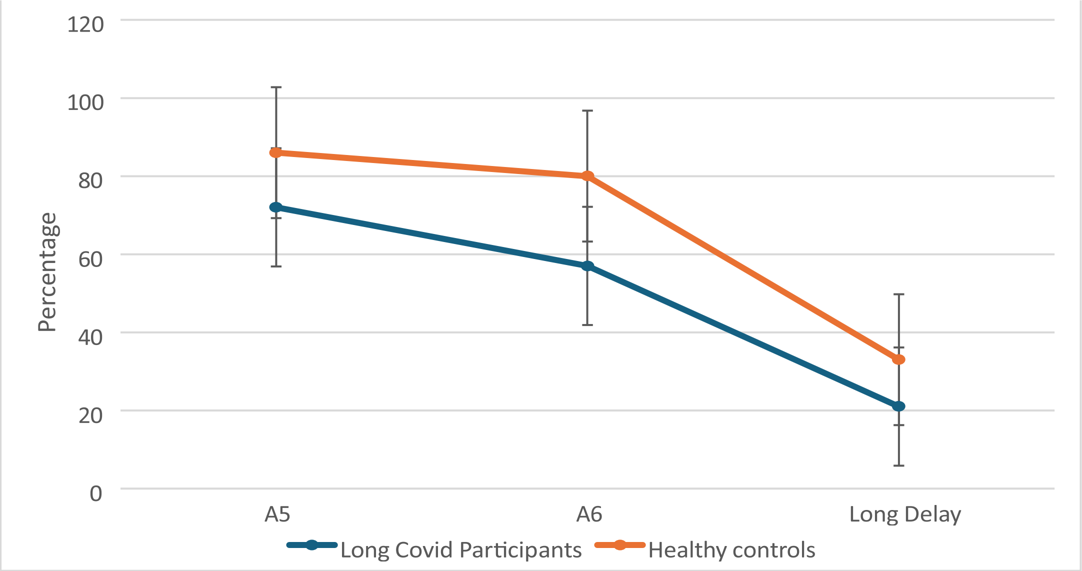


Figure 24. Information Retention of three points in time for List Learning



Correlations

Pearson correlation coefficients were computed to assess relationships between LCSI scores and other variables. was no significant relationship between LCSI and the total number of impaired tasks (*r* =.272, *p* =.068). When assessing relationships between LCSI and raw scores on the BMIPB-II subtests, there were no significant relationship between LSCI and any subtest. There were no correlations between ASI and performance scores.

Assessment Three

The scores for pwLC at Assessment Three were compared against the normative data. Performance in all sub-tests, with the exception of Design Learning and recognition, remained significantly poorer than the normative data, as shown in Table 15.

Table 15. Comparison of performance between pwLC and normative samples on sub-tests of the BMIPB-II at Assessment Three

Sub-Test	**Sample M** ***(SD)***	**Normative M** ***(SD)***	**Cohen's *d***	***t*-value**	**Significance (*P*-value)**
Story Immediate Recall	21.66 *(10.62)*	31.00 *(9.13)*	0.94	5.25	< .001
Story Short Delay Recall	20 *(10.93)*	28.00 *(8.75)*	0.79	4.58	< .001
List Learning	43.05 *(12.05)*	55.00 *(8.67)*	1.13	6.63	< .001
Word Recognition (item)	22.07 *(4.65)*	28.00 *(1.56)*	1.70	11.70	< .001
Word Recognition (source)	20.61 *(5.51)*	28.00 *(2.81)*	1.68	10.71	< .001
Design Learning	36.76 *(12.33)*	40.00 *(9.69)*	0.29	1.66	.097
Design Recognition (item)	36.25 (6.31)	36.00 (*3.96*)	0.04	-0.28	.774
Design Recognition (source)	7.89 *(2.26)*	8.00 *(2.35)*	0.04	0.25	.800
Speed of Information Processing	53.92 *(19.81)*	69.00 *(13.00)*	0.90	5.37	< .001

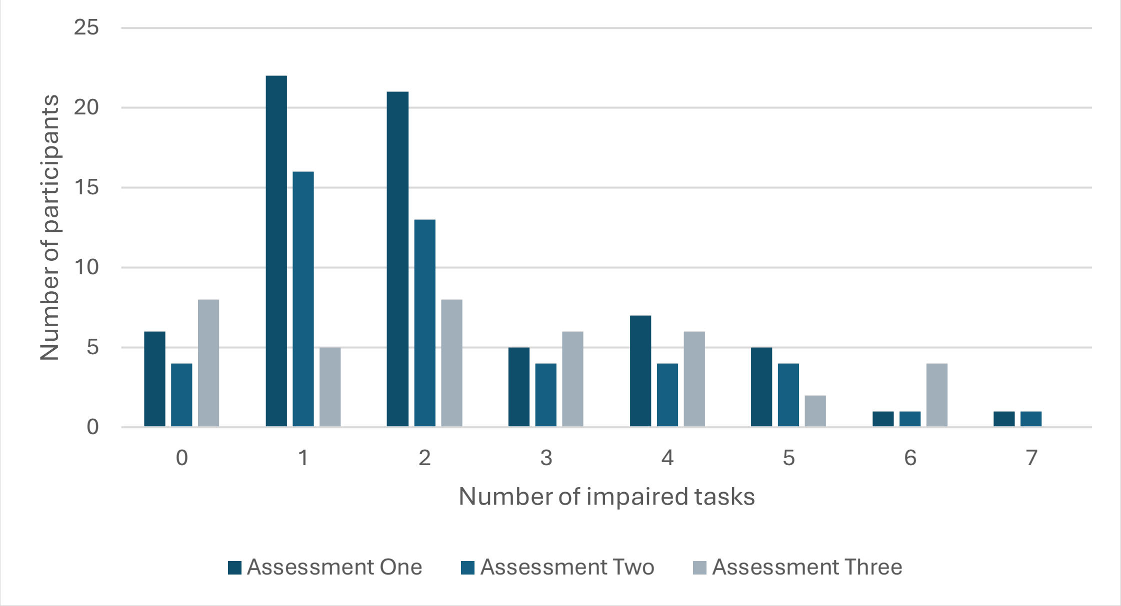
T-tests were used to compare performance for List Learning and Word Recognition were compared to the control data. Word Recognition (item) and Word Recognition (source) remained significantly lower for pwLC compared to controls but there was no significant difference in List Learning as shown in Table 16.

Table 16. Comparison of performance between pwLC and online controls on subtests of the BMIPB-II at Assessment Three

Sub-Test	**PwLC** **M (*SD*)** **N = 39**	**Control** **M (*SD*)** **N = 49**	**Cohen's *d***	***t*-value**	**Significance** **(*p*-value)**
List Learning	43.05 (12.05)	47.36 (9.57)	0.40	1.87	.064
Word Recognition (item)	22.08 (4.65)	24.87 (3.41)	0.69	3.24	< .001
Word Recognition (source)	20.62 (5.51)	23.28 (4.18)	0.55	2.56	< .001

As done in the previous assessments, the total number of impairments were explored. Out of the seven tasks, impairment was seen across six tasks as shown in Figure 25. These are the participants who did all three assessments.

Figure 25. Impaired tasks at all Assessments



Participants showed impairments across all sub-tests, except for Design Recognition Source, as shown in Figure 26. As expected, and observed in Assessments One and Two, the sub-test with the higher impairment was the Word Recognition Task, which suggests this was also problematic for pwLC who took part in Assessment Three. Figure 26 shows impairments at each assessment, as each individual may have endorsed more than one impairment, the total N is larger than the sample sizes.

Figure 26. Impairments on sub-tests of the BMIPB-II at Assessment Three

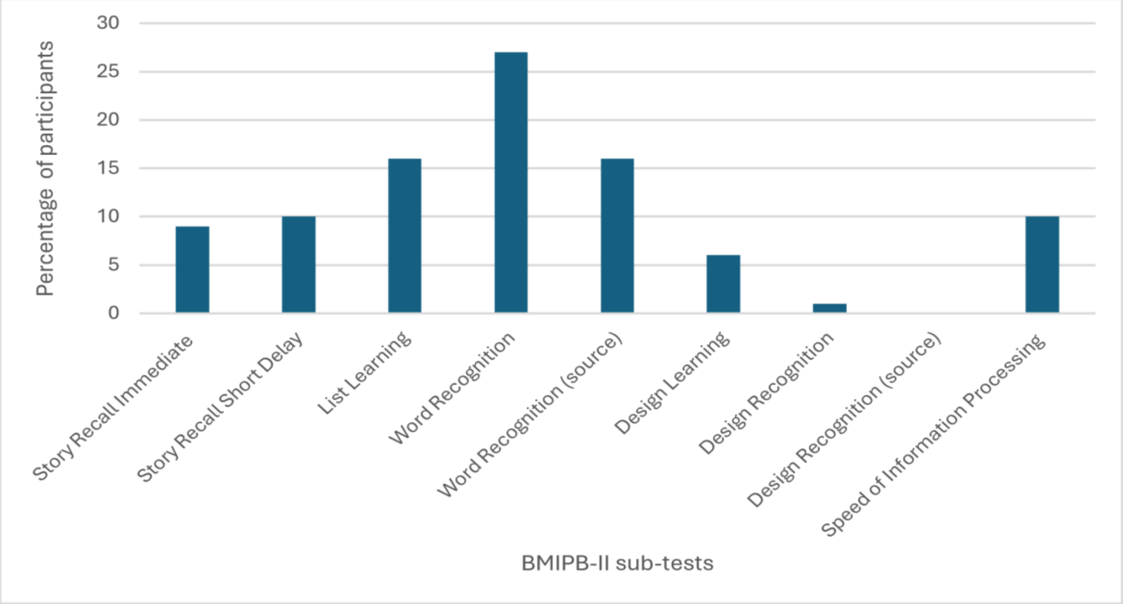
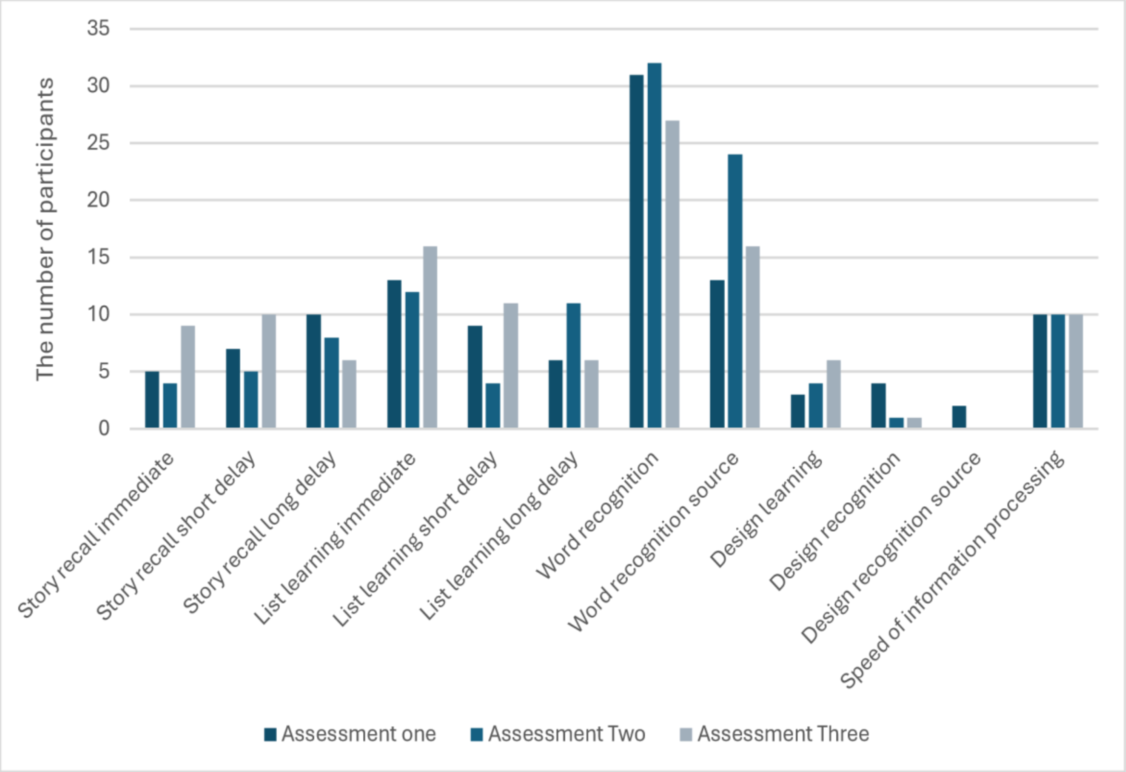


Figure 27. The number of participants in the impaired range for each sub-test at different Assessments.



Correlations

Pearson correlation coefficient were computed to assess relationships between LCSI scores and other variables. There was a significant relationship between LSCI and number of impaired tasks (*r* =.343, *p* =.033). When assessing relationships between LCSI and raw scores on the BMIPB-II subtests, there was a significant relationship between LSCI and SOIP (*r* = -.383, *p* = .016) . There were no correlations between ASI and performance.

Results: Cognitive Performance on the Self-Guided Task

Assessment One

The data were visually inspected to identify response patterns indicative of participants not doing the task correctly or as intended. Specifically, we targeted participants whose hit rate (old items judged as old) was below 40% or whose false alarm rate (new items judged as old) exceeded 60%. This data check resulted in six control participants being excluded for repetitive responses (resulting in high hit rates combined with high false alarm rates). Two LC participants were excluded as their data suggested a misunderstanding of task requirements as they had low hit rates and high false alarms. Therefore, the final sample for this analysis consisted of 49 controls and 66 LC participants. In addition to unequal sample sizes, the item and source memory variables were not normally distributed in Shapiro-Wilk tests, therefore, nonparametric Mann-Whitney *U* tests were used to compare performance between groups.

For the Word Categorisation task, these analyses showed that the percentage of correct responses did not significantly differ between pwLC (*N* = 66, *Median* = 96.92, *M* = 95.94, *SD* = 3.85) and controls (*N* = 49, *Me* = 97.69, *M* = 96.48, *SD* = 3.981, *U* = 1372.50, *z* = -1.30, *p* = .165, *d* = -.12, no effect) which demonstrates pwLC were able to complete this task as accurately as control participants

Due to technical issues with the application for this task, Word Categorisation response times were only recorded for 40 LC participants (61% of the sample), however, there were no significant differences in correct mean response times between those pwLC (*N* = 40, *Me* = 1350, *M* = 1473.19, *SD* = 431, range 949 3000ms) and controls (*N* = 49, *Me*= 1293, *M* = 1363.94, *SD* = 358, range 8562838ms, *U* = 1117.000, *z* = 1.130, *p* = .258, *d* = .02, no effect).

For hits overall (old items judged as old, including both 'probably old' & 'definitely old' responses) there were significant differences between groups. PwLC (*N* = 66, *Me* = 62.69, *M* = 59.09, *SD* = 21.26, range 10.00-95.38) had significantly fewer hits compared to controls (*N* = 49, *Me* = 75.36, *M* = 75.14, *SD* = 12.33, range 47.69-98.46, *U* =1019, *z* = -3.383, *p* = .001, *d* = -.315, medium effect size). For high confidence hits (old items judged as old, 'definitely old' responses only) controls (*N* =

49, *Me* = 67.69, *M* = 62.48, *SD* = 22.53, range 0 - 96.92) also performed significantly better than pwLC (*N* = 66, *Me* = 39.61, *M* = 40.55, *SD* = 24.73, range 0- 95.38), *U* = 972.00, *z* = -3.649, *p* = < .001, *d* = -.340, medium effect size).

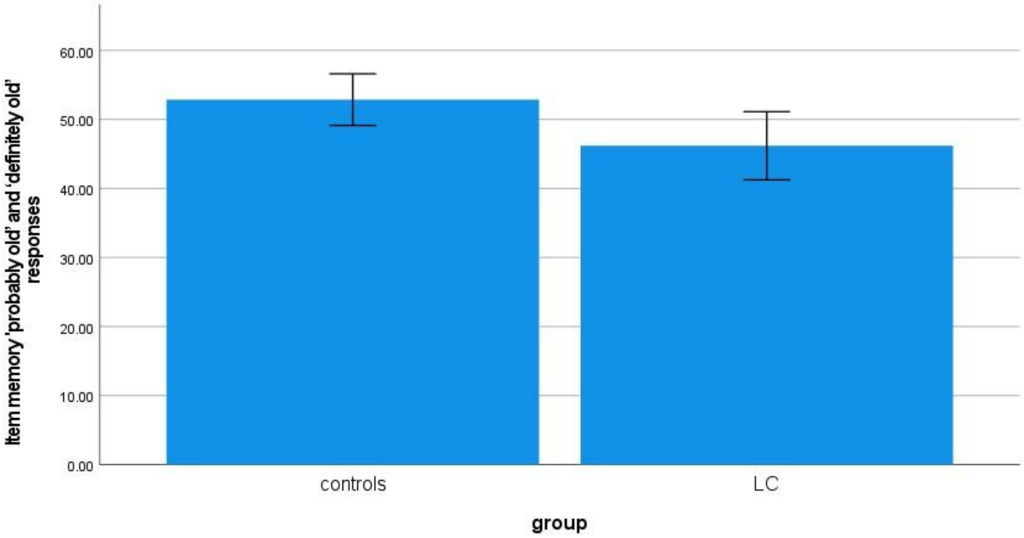
For false alarms overall (new items judged as old, 'probably old' & 'definitely old' responses) pwLC (*N* = 66, *Me* = 10.71, *M* = 14.64, *SD* = 12.49 , range 0-57.14) were significantly better than controls (*N* = 49, *Me* = 17.14, *M* = 22.26, *SD* = 14.80, range 00.00 – 65.71.71, *U* = 1147.500, *z* =-2.659 , *p* = .008, *d* = -.247, medium effect size). The same was true for high-confidence false alarms (new items judged as old, 'definitely old' only) where pwLC (*N* = 66, *Me* = 4.28, *M* = 6.53, *SD* = 8.177, range 0 - 35.71) had fewer false alarms than controls (*N* = 49, *Me* = 10.00, *M* = 14.81, *SD* = 14.71, range 0 - 65.71, *U* = 1132.500, *z* =-2.755, *p* = .006, *d* = -.256, medium effect). This suggests that pwLC were more cautious with their responses than controls (i.e., overall, less likely to say that an item had been seen before).

Item Memory

Item memory performance was calculated by subtracting the false alarm rate (i.e., the proportion of 'probably old' and 'definitely old' responses to new items) from the hit rate (i.e., probably old' & 'definitely old' responses). Secondly, high-confidence item memory performance was calculated by subtracting the high-confidence false alarm rate (i.e., the proportion of 'definitely old' responses to new items) from the high confidence hit rate (i.e., the proportion of 'definitely old' responses to old items).

There were no statistically significant differences between pwLC (*N* = 67, *Me* = 43.24, *M* = 44.45, *SD* = 20.92, range -6.37 – 78.46) and controls (*N* = 49, *Me* = 52.52, *M* = 52.88, *SD* = 13.00, range 21.98 – 86.48, *U* = 1308.50, *z* = -1.745, *p* = .081, *d* = -.16, small effect size). This suggests some preservation of item recognition ability even though more pwLC scored below chance compared to controls as illustrated in Figure 28. However, when exploring high-confidence item memory, pwLC had significantly lower item memory compared to controls. There were more pwLC scoring lower on item memory (*N* = 67, *Me* = 33.73, *M* = 34.02, *SD* = 21.83, range 0 – 77.69) compared to controls (*N* = 49, *Me* = 48.35, *M* = 47.66, *SD* = 17.98, range 0 – 82.42, *U* = 1101.500, *z* = -2.918, *p* = .004, d = .27, small effect size). This suggests that while pwLC were largely able to remember items, they were not as confident as controls at identifying those items.

Figure 28. Item memory performance in pwLC and controls.



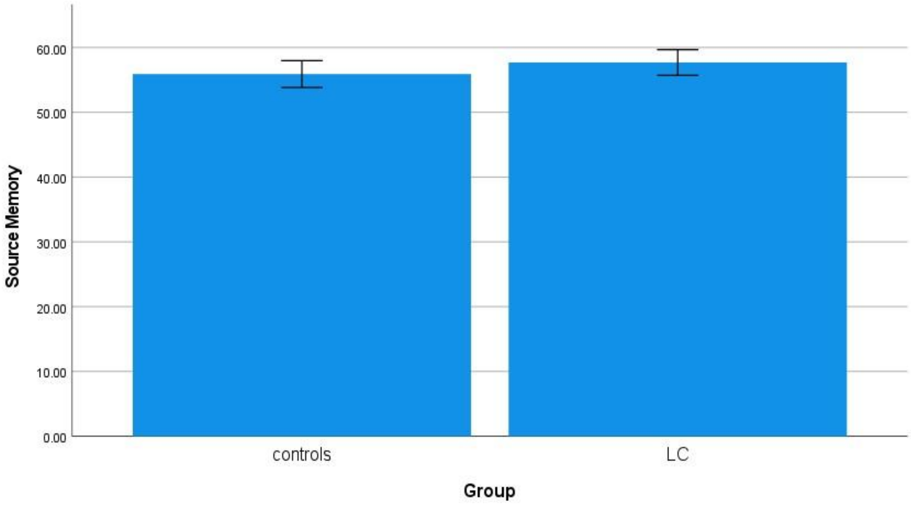
Note that zero represents chance level performance and error bars demonstrate the standard error of the mean.

Source Memory

Overall source memory was calculated by removing all ‘unsure’ responses and calculating the proportion of correct answers (correctly attributed sources divided by the total number of correctly attributed sources and incorrectly attributed sources).

For source memory overall, there were no statistically significant differences in performance. PwLC (*N* = 66, *Me* = 57.17, *M* = 58.13, *SD* = 9.020, range 46.15 – 88.06) performed similarly to controls (*N* = 49, *Me* = 54.26, *M* = 55.91, *SD* = 7.212, range 43.85 – 75.38, *U* =1824.500, *z* = 1.174, *p* = .240, *d* = -.10, small effect size). This may demonstrate preservation of source memory in pwLC. PwLC also scored above chance as illustrated in Figure 29. Furthermore, when exploring high confidence source memory, there were no significant differences between pwLC (*N* = 66, *Me* = 56.63, *M* = 58.16, *SD* = 10.62, range 44.07 – 93.86) and controls (*N* = 49, *Me* = 56.15, *M* = 57.03, *SD* = 7.604, range 42.55 – 75.19, *U* =1635.500, *z* = .105, *p* = .917, *d* = .00, no effect), suggesting that pwLC made accurate source memory attributions regardless of confidence.

Figure 29. Source memory performance in pwLC and controls.



Correlations

Next, Pearsons's correlations were performed to explore the relationships between key variables (high-confidence item memory that was found to be affected by LC, QoL, fatigue and the LCSI). There was no relationship between high-confidence item memory and LCSI (*r* = -.168, *p* = .178), QoL scores (*r* = .180, *p* = .054) or fatigue scores (*r* = -.136, *p* = .148).

Assessment Two

The inspection of data that was used for Assessment One was applied to this data set. Seven LC participants were excluded as their data suggested a misunderstanding of the task, with six of the seven having hits below 40% and 0% for source memory. Therefore, a final sample of 39 LC participants was included for these analyses and compared against the same group of 49 controls were included for Assessment One. Like Assessment One, the item and source memory variables were not normally distributed in Shapiro- Wilk tests, therefore, non-parametric Mann Whitney *U* tests were used to compare performance between groups.

For the Word Categorisation task, the results revealed that the percentage of correct answers did significantly differ between pwLC (*N* = 39, *Me* = 96.92, *M* = 95.52, *SD* = 3.71, range 83.07-100) and controls (*N* = 49, *Me* = 97.69, *M* = 96.48, *SD* = 3.981; *U*= 715.000, *z* = -2.033, *p* = .042, *d* = .21, small effect size) which suggests pwLC have poorer ability to perform on the task compared to controls at Assessment Two but not at Assessment One.

Similar to Assessment One, there were no significant differences between Word Categorisation correct mean response times between pwLC (*N* = 39, *Me* = 1357, *M* = 1391, *SD* = 286.35, range 892 -2126 Ms) and controls (*N* = 49, *Me*= 1293, *M* = 1363, *SD* = 358, range 856-2838 Ms; *U* = 1051.000, *z* = .802, *p* = .422, *d* = .08, small effect size). This indicates that the response speed of pwLC remained comparable to that of controls in the second assessment.

For overall hits, there were significant differences between groups that were comparable to the findings from Assessment One. PwLC (*N* = 39, *Me* = 70.00, *M* = 68.04, *SD* = 15.80, range 18.45-90.76) had significantly fewer hits compared to controls (*N* = 49, *Me* = 75.36, *M* = 75.14, *SD* = 12.33, range 47.69- 98.46; *U* =710.500, *z* = -2.059, *p* = .040, *d* = -.21, small effect size). For high-confidence hits, controls (*N* = 49, *Me* = 67.69, *M* = 62.48, SD = 22.53, range 0- 96.92) also performed significantly better than pwLC (*N* = 39, *Me* = 39.23, *M* = 42.20, *SD* = 24.75, range 0 - 84.61; *U* = 509.500, *z* = -3.747, *p* < .001, *d* = -.39, small effect size).

For overall False Alarms, there were no significant differences between pwLC (*N* =39, *Me* = 14.28, *M* = 17.61, *SD* = 15.06 , range 0-58.57) and controls (*N* = 49, *Me* = 17.14, *M* = 22.26, *SD* = 14.80, range 0 – 65.71; *U* = 742.000, *z* =-1.795 , *p* = .073, *d* = -.19, small effect size). For high-confidence False Alarms, pwLC had significantly fewer false alarms (*N* = 39, *Me* = 2.85, *M* = 7.54, *SD* = 10.21, range 0- 48.57) compared to controls (*N* = 49, *Me* = 10.00, *M* = 14.81, *SD* = 14.71, range 0 - 65.71; *U* = 634.500, *z* =-2.708, *p* = .007, *d* = -.28, small effect size), similar to Assessment One.

Item Memory

There were no statistically significant differences in overall Item memory performance between pwLC (*N* = 39, *Me* = 49.67, *M* = 50.42, *SD* = 15.75, range 18.46-81.87) and controls (*N* = 49, *Me* = 52.52, *M* = 52.88, *SD* = 13.00, range 21.98 – 86.48; *U* = 876.000, *z* = .668, *p* = .504, *d* = .07, small effect size).

When exploring high confidence item memory, pwLC scored lower (*N* = 39, *Me* = 35.38, *M* = 34.66, *SD* = 20.72, range 0 – 82.42) compared to controls (*N* = 49, *Me* = 48.35, *M* = 47.66, *SD* = 17.98, range 0 – 82.42), which was significantly different (*U* = 593.500, *z* = -3.041, *p* = .002, *d* = -.32, large effect size). This suggest that while pwLC were able to remember items, they were not as confident as controls at identifying items as definitely old.

Source Memory

For overall Source memory, there were no statistically significant differences in performance between pwLC (*N* = 49, *Me* = 56.92, *M* = 58.39, *SD* = 8.74, range 46.08 – 80.49) and controls (*N* = 49, *Me* = 54.26, *M* = 55.91, *SD* = 7.212, range 43.85 – 75.38; *U* =1100.00, *z* = 1.214, *p* = .225, *d* = .12, large effect size), which indicates preservation of Source memory. Furthermore, when exploring high confidence Source memory, there was no significant difference between pwLC (*N* = 39, *Me* = 58.06, *M* = 59.19, *SD* = 9.81, range 40.63 – 81.13) and controls either (*N* = 49, *Me* = 56.15, *M* = 57.03, *SD* = 7.604, range 42.55 – 75.19; *U* =1070.000, *z* = .962, *p* = .336, *d* = .10, large effect size), showing that pwLC performed similarly to controls when source memory items were recognised with high confidence.

Correlations

Pearson correlations were calculated to explore the relationships between key variables (high-confidence Item memory, Word Categorisation performance, QoL, fatigue and LCSI). There was a significant correlation between high confidence item memory and LCSI *(r* = .464, *p* = .003) and QoL (*r* = .283, *p* = .008) and high confidence and word categorisation performance (*r* = .368, *p* = .005). There was no relationship between high confidence item memory and fatigue (*r* = .164, *p* = .126) but there was a significance between high confidence item memory and QoL (*r* = .283, *p* = .008).

Assessment Three

The same inspection of data was applied again to this data set. Although four LC participants did have a hit rate below 40%, their source and item memory were over 50% suggesting understanding of the task, thus they were not excluded. A final sample of 28 LC participants and the same group of 49 controls were included for these analyses. The item and source memory variables were not normally distributed in Shapiro- Wilk tests, therefore, nonparametric Mann-Whitney *U* tests were used for comparing performance between groups.

For the Word Categorisation task, the results revealed that the percentage of correct answers did not significantly differ between pwLC (*N* = 28, *Me* = 96.91, *M* = 96.01, *SD* = 3.14, range = 87.67 – 100.00) and controls (*N* = 49, *Me* = 97.69, *M* = 96.48, *SD* = 3.981; *U* = 524.500, *z* = -1.714, *p* = .086, *d* = 0.13, small effect size). There were no significant differences between Word Categorisation correct mean response times between pwLC (*N* = 28, *Me* = 1286, *M* = 1417, *SD* = 507, range = 919 - 3528ms) and controls (*N* = 49, *Me* = 1293, *M* = 1363.94, *SD* = 358, range = 8562838ms, *U* = 694.000, *z* = .085, *p* = .932, *d* = 0.13, small effect size).

For overall Hits, there were significant differences between groups. PwLC (*N* = 28, *Me* = 63.46, *M* = 62.93, *SD* = 18.40, range 21.54 – 90.00) had significantly fewer hits compared to controls (*N* = 49, *Me* = 75.36, *M* = 75.14, *SD* = 12.33, range 47.69-98.46; *U* = 429.000, *z* = -2.722, *p* = .006, *d* = -.31, small effect size). For high confidence hits, controls (*N* = 49, *Me* = 67.69, *M* = 62.48, *SD* = 22.53, range 0-96.92) also performed significantly better than pwLC (*N* = 28, *Me* = 41.15, *M* = 41.51, *SD* = 25.14, range 0- 85.38; *U* = 355.000, *z* = -3.506, *p* = <.001, *d* = -.39, small effect size).

For overall False Alarms, there were no significant differences between pwLC (*N* = 28, *Me* = 12.85, *M* = 18.33, *SD* = 13.97 , range = 01.43-51.43) and controls (*N* = 49, *Me* = 17.14, *M* = 22.26, *SD* = 14.80, range = 0 – 65.71.71; *U* = 562.000, *z* =-1.314, *p* = .189, *d* = -.14, small effect size). For high-confidence false alarms, pwLC had significantly fewer false alarms (*N* = 28, *Me* = 2.85, *M* = 7.50, *SD* = 08.96, range = 0- 30.00) than controls (*N* = 49, *Me* = 10.00, *M* = 14.81, *SD* = 14.71, range = 0 - 65.71; *U* = 455.500, *z* =-2.449, *p* = .014, *d* = -. 27, small effect size), suggesting like in previous assessments, that pwLC applied more caution before determining that words had been encountered before.

Item Memory

There was no statistically significant difference in overall Item memory performance between pwLC (*N* = 28, *Me* = 47.41, *M* = 44.60, *SD* = 18.94, range = 0.88- 71.10) and controls (*N* = 49, *Me* = 52.52, *M* = 52.88, *SD* = 13.00, range = 21.98 – 86.48; *U* = 536.000, *z* = -1.588, *p* = .112, *d* = .18, small effect size). For high-confidence item memory, pwLC performed worse than controls. There were more pwLC scoring lower (*N* = 28, *Me* = 37.91, *M* = 34.01, *SD* = 19.86, range 0 – 66.37) than controls (*N* = 49, *Me* = 48.35, *M* = 47.66, *SD* = 17.98, range 0 – 82.42) which was significantly different (*U* = 424.500, *z* = -2.769, *p* = .006, d = .31, small effect size). This suggests that pwLC had reduced high-confidence item memory performance.

Source Memory

For overall Source memory, there were no significant differences in performance between pwLC (*N* = 28, *Me* = 53.84, *M* = 56.11, *SD* = 6.38, range 48.84 – 76.92) and controls (*N* = 49, *Me* = 54.26, *M* = 55.91, *SD* = 7.212, range 43.85 – 75.38; *U* =705.500, *z* = .207, *p* = .836, *d* = -.02, no effect). Also, when exploring high confidence Source memory, there was no significant difference between pwLC (*N* = 28, *Me* = 53.40, *M* = 54.95, *SD* = 8.33, range 36.36 – 73.91) and controls (*N* = 49, *Me* = 56.15, *M* = 57.03, *SD* = 7.604, range 42.55 – 75.19; *U* = 581.500, *z* = -1.107, *p* = .268, *d* = .12, small effect size).

Correlations

Pearson correlations were performed. High confidence item memory was not significantly correlated with LSCI (*r* = .082, *p* = .680), but it was with fatigue (*r* = -.250, *p* = .029) and QoL (*r* = .236, *p* = .039).

With hindsight, item recognition memory in this study may have been better measured using area under the receiver operating characteristic (ROC) curve, rather than the measure of hits minus false alarms. The simpler measure of hits minus false alarms can blur sensitivity and response bias (Brady et al., 2023; Norman & Wickelgren, 1965). This will be discussed in more detail in the thesis limitations in Chapter Six.

Results: Longitudinal Analyses

Data Collection

Data collection for the three studies spanned a 24-month period, as displayed in Table 17. All participants who completed any assessments at a single time-point or all three assessments were included in these longitudinal analyses.

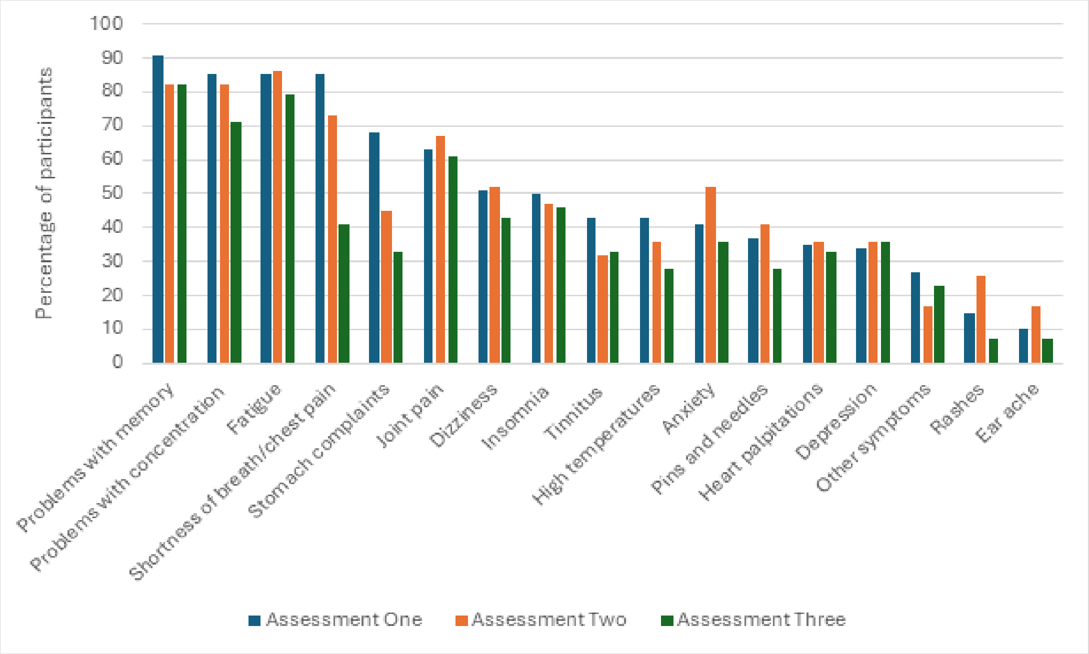
Table 17. Data Collection Timeline

	Assessment One Initial sample	**Assessment Two**	**Assessment Three**
	$N = 68$	$N = 46$	$N = 39$
		67.65% of initial sample	57.35% of initial sample
Date	March 2023 – July 2023	October 2023 – March 2024	December 2024 – March 2025
Average months between assessments			
1 & 2	5.33 months (SD = 1.31)		
2 & 3	13.71 months (SD = 1.14)		
1 & 3	19.05 months (SD = 1.41)		

Characteristics

Participants had been living with LC between 24 and 60 months at the time of the final assessment, the average was 44.20 months ($SD = 11.79$). The number of current self-reported LC symptoms ranged from zero to 39 across the assessments. There was an average of 7.72 ($SD = 4.21$) symptoms reported at Assessment One, an average of 9.33 ($SD = 4.69$) at Assessment Two and an average of 8.51 ($SD = 4.01$) at Assessment Three. A repeated-measures ANOVA revealed that the total number of reported symptoms did not significantly differ across the three time points (F (1.34, 50.74) = 1.49, $p = .233$, partial $\eta^2 = .038$). The prevalence of the various self-reported symptoms is displayed in Figure 30. The most frequently reported symptoms across assessments were fatigue, problems with memory and problems with concentration.

Figure 30. Prevalence of LC symptoms across Assessments.



Linear Mixed Models Analyses

A series of linear mixed modelling (LMM) were conducted to examine all outcome variables assessed on pwLC across assessments. LMM was selected for longitudinal analyses, as unlike other traditional repeated measures models, it is robust even with unequal sample sizes and can accommodate missing data (Field, 2017). Missing data on outcome variables were handled by using the maximum likelihood estimation method; therefore, no imputation of outcome variables was performed. The final sample included *N* = 68 pwLC for all models (except for Word Categorisation Speed where it was *N* = 57 as the data for response times for some participants at Assessment One were not recorded).

Following best practice identified by Meteyard and Davies (2020), assumptions were checked for each model. Although Shapiro-Wilks test was significant on some of the models, visual inspection of residual histogram and Q-Q plots suggested normality. Plots of residuals and predicted values suggested linear relationships and homoscedasticity. Variance inflation factors (VIFs) for fixed predictors were all below five, indicating no evidence of multicollinearity.

The LMM included Assessment as a repeated measures effect with a heterogeneous first-order autoregressive (AR1) covariance structure and participants as a random effect. The models used performance scores as dependent variables and Assessment (time), Fatigue, Acute Severity and LC Severity as covariates. Fatigue was entered as a categorical variable (Low vs. High) rather than continuous, as visual inspection showed it was binomially distributed. However. Acute and LC Severity were both entered as continuous variables as they were normally distributed. Fatigue, Acute Severity and LC Severity were also included as interactions. All analyses were completed using IBM SPSS version 27.0 and effects of p < .05 were considered significant.

Cognitive Performance on The Examiner Administered Tasks

The results from the LMM for the examiner administered tasks are presented in

Table 18

Table 18. LMM results for examiner administered tasks.

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
Story Recall Immediate *	Assessment	16.172	3.17	0.78	**< .001**	1.60, 4.75
	Fatigue	1.231	16.09	14.50	.270	-12.74, 44.93
	Acute Severity	3.173	1.95	1.09	.078	-022, 4.13
	LC Severity	0.111	0.09	0.28	.740	-0.47, 0.67
	Fatigue x Acute Severity	2.596	-2.29	1.42	.111	-5.13, 0.53
	Fatigue x LC Severity	1.694	-0.42	0.33	.197	-1.08, 0.22
	Acute Severity x LC Severity	1.878	-0.03	0.02	.174	-0.08, 0.01
	Fatigue x LC x Acute	2.895	0.05	0.03	.092	-0.00, 0.11

Story Recall Short Delay *	Assessment	17.167	3.97	0.91	**< .001**	1.96, 5.61
	Fatigue	1.624	21.33	16.73	.205	-11.85, 54.51
	Acute Severity	3.766	2.41	1.24	.055	-0.05, 4.89

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
	LC Severity	0.650	0.26	0.32	.422	-0.37, 0.89
	Fatigue x Acute Severity	2.646	-2.67	1.64	.107	-5.93, 0.58
	Fatigue x LC Severity	2.803	-0.63	0.37	.097	-1.38, 0.11
	Acute Severity x LC Severity	3.152	-0.05	0.02	.078	-0.11, 0.00
	Fatigue x LC x Acute	3.663	0.06	0.03	.058	-0.00, 0.13
	Assessment	15.593	3.24	0.82	**< .001**	1.60, 4.89
	Fatigue	5.056	30.27	13.46	**.027**	3.54, 57.01
	Acute Severity	3.946	1.98	1.00	**.050**	-8.76, 3.97

Story Recall Long Delay *	LC Severity	1.015	0.27	0.26	.316	-0.26, 0.80
	Fatigue x Acute Severity	4.396	-2.77	1.32	**.039**	-5.40, -0.14
	Fatigue x LC Severity	5.801	-0.75	0.31	**.018**	-1.36, -0.13

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
	Acute Severity x LC Severity	3.162	-0.04	0.02	.078	-0.09, 0.00
	Fatigue x LC x Acute	5.089	0.06	0.02	**.026**	0.00, 0.12
List Learning A5 *	Assessment	0.472	0.18	0.27	.494	-0.35, .072
	Fatigue	0.320	2.50	4.43	.573	-6.27, 11.29
	Acute Severity	0.874	0.32	0.34	.352	-0.36, 1.01
	LC Severity	0.045	0.01	0.08	.831	-0.15, 0.19
	Fatigue x Acute Severity	0.318	-0.24	0.43	.574	-1.10, 0.67
	Fatigue x LC Severity	0.420	-0.06	0.09	.518	-0.26, 0.13

	Acute Severity x LC	0.170	-0.00	0.00	.681	-0.01, 0.01
	Severity					
	Fatigue x LC x Acute	0.300	0.00	0.00	.585	-0.01, 0.02
List Learning A6 *	Assessment	4.476	0.55	0.26	**.038**	0.03, 1.08

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
	Fatigue	0.101	-1.41	4.44	.751	-10.25, 7.42
	Acute Severity	0.035	0.06	0.35	.851	-0.46, 0.78
	LC Severity	3.577	-0.17	0.09	.061	-0.36, 0.00
	Fatigue x Acute Severity	0.011	-0.04	0.43	.915	-0.91, 0.82
	Fatigue x LC Severity	1.389	0.12	0.10	.241	-0.08, 0.32
	Acute Severity x LC Severity	1.002	0.00	0.00	.319	-0.00, 0.02
	Fatigue x LC x Acute	0.411	-0.00	0.00	.523	-0.02, 0.01

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List Learning Long Delay *	Assessment	0.465	0.16	0.24	.497	-0.32, 0.66
	Fatigue	0.048	-0.93	4.24	.827	-9.35, 7.48
	Acute Severity	0.500	-0.22	0.32	.481	-0.86, 0.41
	LC Severity	1.956	-0.11	0.08	.164	-0.28, 0.04
	Fatigue x Acute Severity	0.245	0.20	0.41	.622	0.62, 1.03
Word Recognition *	Assessment	23.768	2.11	0.43	**< .001**	1.25, 2.97
	Fatigue	0.734	-6.69	7.78	.393	-22.07, 8.73
	Acute Severity	3.744	-1.16	0.60	.055	-2.35, 0.02
	LC Severity	4.338	-0.30	0.14	**.039**	-0.59, -0.01

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Dependent variable	Fixed Factors	*F*	*b*	SE b	*p*	95% CI
	Fatigue x LC Severity	0.728	0.08	0.09	.395	-0.11, 0.27
	Acute Severity x LC Severity	2.593	0.01	0.00	.110	-0.00, 0.02
	Fatigue x LC x Acute	1.509	-0.01	0.00	.222	-0.02, 0.00
	Fatigue x Acute Severity	0.615	0.59	0.76	.434	-0.91, 2.10
	Fatigue x LC Severity	0.817	0.15	0.16	.368	-0.18, 0.48
	Acute Severity x LC Severity	3.155	0.02	0.01	.078	-0.00, 0.05

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	Fatigue x LC x Acute	1.016	-0.01	0.01	.315	0.04, 0.01

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
Word Recognition source *	Assessment	17.976	2.00	0.47	**< .001**	1.06, 2.94
	Fatigue	2.433	-13.00	8.33	.121	-29.50, 3.50
	Acute Severity	1.512	-0.79	0.65	.221	-2.08, 0.48
	LC Severity	3.475	-0.28	0.45	.065	-0.59, 0.01
	Fatigue x Acute Severity	1.827	1.10	0.81	.179	-0.51, 2.71

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	Fatigue x LC Severity	1.802	0.23	0.17	.182	-0.11, 0.58
	Acute Severity x LC Severity	1.984	0.01	0.01	.165	-0.00, 0.04
	Fatigue x LC x Acute	1.890	-0.02	0.01	.172	-0.05, 0.01
Design Learning *	Assessment	10.281	2.97	0.92	**.002**	1.13, 4.82
	Fatigue	2.332	26.46	17.32	.130	-7.86, 60.78
	Acute Severity	1.650	1.69	1.32	.201	0.91, 4.31

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Design Learning source *	Assessment	5.434	0.46	0.19	**.022**	0.60, 0.56
	Fatigue	2.930	6.37	3.70	.089	-0.99, 13.68
	Acute Severity	0.358	0.16	0.27	.551	-0.37, 0.70
	LC Severity	0.151	.02	0.06	.698	-0.10, 0.16
	Fatigue x Acute Severity	4.184	-0.74	0.36	**.043**	-1.46, -0.02
	Fatigue x LC Severity	2.865	-0.13	0.08	.093	-0.30, 0.02

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
	LC Severity	0.829	0.30	0.33	.364	-0.35, 0.96
	Fatigue x Acute Severity	2.551	-2.71	1.70	.113	-6.09, .065
	Fatigue x LC Severity	3.263	-0.70	0.38	.073	-1.47, 0.06
	Acute Severity x LC Severity	1.760	-0.04	0.03	.187	-0.10, 0.02
	Fatigue x LC x Acute	3.975	0.07	0.03	**.048**	0.00, 0.14

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
	Acute Severity x LC Severity	0.282	-0.00	0.00	.596	-0.01, 0.00
	Fatigue x LC x Acute	4.202	0.01	0.00	**.042**	0.00, 0.03
Speed of Information Processing*	Assessment	14.852	6.57	1.70	**< .001**	3.18, 9.97
	Fatigue	0.739	25.26	29.38	.392	-32.95, 83.48
	Acute Severity	0.013	-0.26	2.31	.910	-4.85, 4.32
	LC Severity	0.182	-0.24	0.58	.671	-1.39, 0.90
	Fatigue x Acute Severity	1.325	-3.31	2.88	.252	-9.02, 2.39
	Fatigue x LC Severity	0.845	-0.60	0.65	.360	-1.90, 0.69
	Acute Severity x LC Severity	0.087	-0.01	0.05	.768	-0.12, 0.08

	Fatigue x LC x Acute	1.338	0.07	0.06	.250	-0.05, 0.19
Total number of impairments *	Assessment	1.555	-0.17	0.14	.216	-0.45, 0.10

Dependent variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
	Fatigue	1.226	-2.47	2.23	.271	-6.90, 1.95
	Acute Severity	0.202	-0.08	0.18	.653	-0.44, 0.27
	LC Severity	0.440	-0.02	0.04	.508	-0.11, 0.05
	Fatigue x Acute Severity	0.757	0.19	0.21	.386	-0.24, 0.62
	Fatigue x LC Severity	3.998	.10	0.05	**.048**	0.00, 0.20
	Acute Severity x LC Severity	1.250	0.00	0.00	.265	-0.00, 0.01
	Fatigue x LC x Acute	2.871	-0.00	0.00	.093	-0.01, 0.00

* Final LMM including all variables shown significantly improved from initial LMM (-2 Log Likelihood *p* = < 0.05)

As shown in Table 18, the LMM demonstrated that for most of the tasks, except for List Learning, List Learning long delay and total number of impairments, Assessment significantly predicted better cognitive performance. This may suggest recovery over time, although it could also be attributed to practice effects, as the same tests were used three times (albeit with an alternate form in the second assessment). Despite these performance improvements, the total number of impairments defined as scores at or below the 2nd percentile, did not significantly decrease over time which provides evidence of the persistent long-lasting nature of cognitive impairments for some people. Word Recognition and Word Recognition Source remained the most prevalent impairments throughout all three assessments, which may suggest that recognition of verbal information is the most challenging for pwLC.

The main effects of Fatigue and Acute Severity were only significant in Story Recall Long Delay. Higher Fatigue was associated with poorer long-delay performance and Acute severity was at the significance threshold, suggesting that Acute Severity is weakly associated with long-delay performance. Although these main effects were not consistent across tasks they did emerge through interactions. The three-way interaction between Fatigue, Acute Severity and LC Severity was evident in three of the tasks. In Story Recall Long Delay, Design Learning and Design Source memory, this interaction suggests that Fatigue negatively affects performance when Acute Severity scores are higher but as LC Severity increases, the negative impact of this two-way interaction (Fatigue and Acute Severity) decreases. This indicates that pwLC who score lower on the LC Severity but experience high Fatigue and had a more severe acute infection perform poorer in long-term memory, whereas for those more severe LC, the interaction between Fatigue and Acute severity is less predictive of long-term performance. This provides evidence that factors such as Fatigue and Acute Severity do not affect performance in isolation, but their impact depends on LC Severity. The possible explanations for these interactions with LC Severity will be explored in the discussion.

The results of the LMM analyses provide evidence of the relationship between severity of the longer-term condition (LC) and fatigue on the total number of impairments observed. While there was not a significant main effect of fatigue, at higher LC Severity scores there was a stronger effect of Fatigue on the number cognitive impairments.

Cognitive Performance on The Self-Guided Tasks

The results from the LMM for the self-guided tasks are presented in Table 19.

Table 19. LMM results for the Self-Guided Tasks

Dependent variable	**Fixed Factors**	***F***	***b***	**SE *b***	***p***	**95% CI**
Word Categorisation Speed	Assessment	3.250	-77.64	43.07	.077	-164.01, 8.72
	Fatigue	0.053	192.91	839.90	.819	-1475.22, 1867.06
	Acute Severity	0.033	10.91	60.55	.857	-109.23, 131.07
	LC Severity	0.035	-2.47	13.29	.853	-28.95, 24.01
	Fatigue x Acute Severity	0.064	-20.91	82.87	.801	-185.32, 143.48
	Fatigue x LC Severity	0.002	0.83	16.85	.961	-32.71, 34.38
	Acute Severity x LC Severity	0.109	0.44	1.33	.742	-2.21, 3.09
	Fatigue x LC x Acute	0.008	0.14	1.64	.929	-3.12, 3.41
Word Categorisation Accuracy	Assessment	1.431	0.41	0.34	.236	-0.27, 1.10
	Fatigue	0.083	-1.69	5.87	.773	-13.34, 9.95
	Acute Severity	0.036	0.09	0.48	.849	-0.86, 1.05
	LC Severity	0.127	0.04	0.11	.723	-0.18, 0.26

	Fatigue x Acute Severity	0.007	0.04	0.59	.933	-1.12, 1.22

Dependent variable	**Fixed Factors**	***F***	***b***	**SE *b***	***p***	**95% CI**
	Fatigue x LC Severity	0.009	-0.01	0.12	.926	-0.26, 0.24
	Acute Severity x LC Severity	0.582	-0.00	0.01	.447	-0.02, 0.01
	Fatigue x LC x Acute	0.068	0.00	0.01	.794	-0.02, 0.02
Overall Hits	Assessment	0.003	-0.94	1.73	.956	-3.54, 3.35
	Fatigue	2.820	55.85	33.26	.096	-10.02, 121.72
	Acute Severity	0.595	2.11	2.74	.442	-3.30, 7.53
	LC Severity	1.979	0.88	0.63	.162	-0.36, 2.14
	Fatigue x Acute Severity	2.648	-5.49	3.37	.106	-12.18, 1.19
	Fatigue x LC Severity	3.527	-1.34	0.71	.063	-2.76, 0.07
	Acute Severity x LC Severity	0.973	-0.06	0.06	.326	-0.18, 0.06

	Fatigue x LC x Acute	2.504	0.11	0.07	.116	-0.02, 0.25
High Confidence Hits	Assessment	0.023	0.32	2.16	.881	-4.01, 4.66
	Fatigue	0.006	3.25	43.68	.941	-83.40, 89.92

Dependent variable	**Fixed Factors**	***F***	***b***	**SE *b***	***p***	**95% CI**
	Acute Severity	0.015	-0.43	3.54	.902	-7.46, 6.59
	LC Severity	0.000	-0.01	0.84	.986	-1.168, 1.65
	Fatigue x Acute Severity	0.018	0.59	4.46	.894	-8.25, 9.44
	Fatigue x LC Severity	0.025	-0.15	0.96	.875	-2.05, 1.75
	Acute Severity x LC Severity	0.006	0.00	0.08	.938	-0.15, 0.17
	Fatigue x LC x Acute	0.038	-0.08	0.09	.845	-0.20, 0.17

Overall False Alarms	Assessment	0.072	0.30	1.34	.789	-1.95, 2.57
	Fatigue	0.028	3.75	22.49	.868	-40.99, 48.51
	Acute Severity	0.002	0.09	2.19	.965	-4.24, 4.43
	LC Severity	0.230	0.23	0.48	.632	-0.72, 1.19
	Fatigue x Acute Severity	0.004	0.15	2.33	.948	-4.49, 4.79
	Fatigue x LC Severity	0.000	-0.00	0.49	.995	-0.97, 0.97

Dependent variable	**Fixed Factors**	***F***	***b***	**SE *b***	***p***	**95% CI**
	Acute Severity x LC Severity	0.005	-0.00	0.04	.944	-0.09, 0.09
	Fatigue x LC x Acute	0.082	-0.01	0.04	.775	-0.11, 0.08
High-confidence False Alarms	Assessment	2.144	-1.84	1.25	.149	-4.36, 0.68
	Fatigue	3.989	-46.08	23.07	**.048**	-91.71, -0.44
	Acute Severity	0.522	-1.28	1.77	.472	-4.80, 2.23
	LC Severity	0.282	-0.20	0.38	.596	-0.96, .055

	Fatigue x Acute Severity	3.615	4.42	2.32	.059	-0.17, 9.01
	Fatigue x LC Severity	4.320	0.95	0.45	**.040**	0.04, 1.86
	Acute Severity x LC Severity	0.444	0.02	0.03	.507	-0.05, 0.10
	Fatigue x LC x Acute	3.848	-0.08	0.04	.052	-0.17, 0.00
Item memory	Assessment	0.015	-0.18	1.55	.902	-3.20, 2.82
	Fatigue	4.021	63.22	31.52	**.048**	0.70, 125.74
	Acute Severity	0.797	2.34	2.62	.374	-2.85, 7.55

Dependent variable	**Fixed Factors**	***F***	***b***	**SE *b***	***p***	**95% CI**
	LC Severity	2.252	0.88	0.58	.137	-0.28, 2.04
	Fatigue x Acute Severity	4.018	-6.44	3.21	**.048**	-12.82, -0.07
	Fatigue x LC Severity	6.428	-1.67	0.66	**.013**	-2.98, -0.36
	Acute Severity x LC Severity	1.425	-0.06	0.05	.235	-0.18, 0.04

	Fatigue x LC x Acute	4.925	0.14	0.06	**.029**	0.01, 0.27
High-confidence item memory	Assessment	0.276	0.90	1.72	.601	-2.53, 4.34
	Fatigue	0.719	29.51	34.80	.398	-39.48, 98.52
	Acute Severity	0.020	-0.40	2.87	.888	-6.10, 5.29
	LC Severity	0.007	-0.05	0.66	.935	-1.36, 1.26
	Fatigue x Acute Severity	0.534	-2.59	3.55	.467	-9.63, 4.44
	Fatigue x LC Severity	0.528	-0.54	0.74	.469	-2.02, 0.94
	Acute Severity x LC Severity	0.025	0.01	0.06	.875	-0.11, 0.13

Dependent variable	**Fixed Factors**	***F***	***b***	**SE *b***	***p***	**95% CI**
	Fatigue x LC x Acute	0.174	0.03	0.07	.678	-0.11, 0.17
Source memory	Assessment	0.443	0.44	0.67	.508	-0.89, 1.78
	Fatigue	9.257	-42.17	13.86	**.003**	-69.65, -14.70
	Acute Severity	7.279	-2.92	1.08	**.008**	-5.08, -0.77

	LC Severity	13.181	-0.89	0.24	**<.001**	-1.38, -0.40
	Fatigue x Acute Severity	8.236	4.04	1.40	**.005**	1.12, 6.83
	Fatigue x LC Severity	11.273	0.96	0.28	**.001**	0.39, 1.53
	Acute Severity x LC Severity	9.632	0.07	0.02	**.002**	0.02, 0.12
	Fatigue x LC x Acute	6.539	-0.08	0.02	**.003**	-0.14, -0.03
High-confidence source memory	Assessment	1.009	-0.85	0.85	.319	-2.55, 0.84
	Fatigue	2.354	-25.18	16.41	.128	-57.68, 7.31
	Acute Severity	0.819	-1.16	1.28	.367	-3.70, 1.38
	LC Severity	1.125	-0.32	0.30	.291	-0.94, 0.28
	Fatigue x Acute Severity	1.461	2.01	1.66	.229	-1.28, 5.31

Dependent variable	**Fixed Factors**	***F***	***b***	**SE *b***	***p***	**95% CI**
	Fatigue x LC Severity	1.308	0.41	0.36	.255	-0.30, 1.12

	Acute Severity x LC Severity	0.638	0.02	0.03	.426	-0.03, 0.08
	Fatigue x LC x Acute	0.797	-0.03	0.03	.374	-0.10, 0.03

The LMM demonstrated contrasting results for the self-guided and examiner administered tasks for the main effect of Assessment. For the self-guided tasks, Assessment was not a significant main effect, indicating performance did not change over time, which contrasts with the examiner administered tasks where performance was frequently associated with improved Assessment.

For high-confidence False Alarms, pwLC with higher Fatigue made fewer errors than participants with lower Fatigue. However, this effect was reduced as evidenced by the significant interaction of Fatigue with LC Severity. Those with higher LC Severity and lower Fatigue had more False Alarms than those with low LC Severity, suggesting that when LC Severity increases the effect of Fatigue reduces.

The main effect of Fatigue for Item memory revealed an unexpected result, that those with higher Fatigue actually had better item performance. However, this effect changed as evidenced in the Fatigue and Acute Severity interaction, whereby pwLC with high Fatigue and high Acute Severity scores had poorer performance than those with low fatigue and low Acute Severity scores. This effect of Fatigue increased in the Fatigue and LC Severity interaction, as LC Severity scores increased, Fatigue had a greater negative impact on performance. The three-way interaction between Fatigue, Acute Severity and LC Severity showed that when both Acute Severity and LC Severity were high, fatigue impacted performance. When LC Severity scores were high, the effects of Fatigue and Acute Severity were reduced.

Source memory results showed numerous significant effects. The main effect of Fatigue indicated reduced Source memory performance, those with higher fatigue had poorer performance. Additionally, higher Acute severity and higher LC Severity scores were also associated with poorer performance. The Fatigue and Acute Severity interaction showed that higher Acute Severity scores reduced the impact of Fatigue on performance, suggesting that Fatigue was more detrimental to Source memory when Acute Severity scores are lower. This was also apparent for the Fatigue and LC Severity interaction. The Acute Severity and LC Severity interaction revealed that pwLC with higher Acute Severity scores, but low LC Severity scores had poorer performance. However, when accounting for the three-way interaction, higher LC scores cancelled out the previous positive interactions, as when Fatigue and Acute Severity was high, LC was significantly associated with worse performance. This three-way interaction contrasts with previous three-way interactions in the examiner administered tasks, as this model shows the negative impact of Fatigue and Acute Severity when accounting for high LC Severity scores. Whereas in the examiner administered tasks, pwLC who scored lower on the LC Severity but high Fatigue and had a more severe acute infection perform poorer in long-term memory, whereas for those more severe LC, the interaction between Fatigue and Acute severity is less predictive of long-term performance.

Functional Outcomes

The results of the LMMs for Quality of Life and the number of daily limitations are presented in Table 20.

Table 20. LMM results for functional outcomes.

Dependent Variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**
QoL *	Assessment	0.303	0.66	1.20	.584	-1.73, 3.05
	Fatigue	2.427	-35.79	22.97	.122	-81.26, 9.67
	Acute Severity	0.286	0.93	1.75	.594	-2.53, 4.41
	LC Severity	0.094	0.13	0.42	.760	-0.71, 0.97
	Fatigue x Acute Severity	0.841	2.60	2.24	.361	-2.38, 6.51
	Fatigue x LC Severity	0.284	0.26	0.49	.595	-0.71, 1.23
	Acute Severity x LC Severity	1.531	-0.48	0.03	.218	-0.12, 0.02
	Fatigue x LC x Acute	0.082	-0.01	0.04	.755	-010, 0.07
Daily Limitations *	Assessment	17.311	-0.26	0.06	**<.001**	-0.39, -0.14
	Fatigue	2.564	1.84	1.15	.112	-0.43, 4.13
	Acute Severity	6.520	0.22	0.08	**.012**	0.04, 0.39
	LC Severity	6.117	0.05	0.02	**.015**	0.10, 0.09
	Fatigue x Acute Severity	1.350	-0.13	0.11	.247	-0.35, 0.09
	Fatigue x LC Severity	1.475	-0.03	0.02	.227	-0.08, 0.01
Dependent Variable	**Fixed Factors**	***F***	***b***	**SE b**	***p***	**95% CI**

	Acute Severity x LC Severity	3.251	-0.00	0.00	.073	-0.00. 0.00
	Fatigue x LC X Acute	0.832	0.00	0.00	.363	-0.00, 0.00

* Final LMM significantly improved from initial LMM as each variable was added (-2 Log Likelihood *p* = < 0.05)

There were no significant main or interaction effects for QoL, however there were significant effects for Daily Limitations. There was a significant decrease in Daily Limitations across Assessments, which suggests perceived improvement over time. Additionally, higher Acute Severity and LC Severity was significantly associated with higher total number of daily limitations indicating that both the acute and long-lasting effects of LC affect Daily Limitations.

Chapter Discussion

The studies within this chapter aimed to explore cognitive performance, specifically memory of pwLC of a working age sample. The lived experiences of pwLC were also explored to gain insight into the daily challenges patients may face. The longitudinal analyses using Linear Mixed Models explored changes in cognitive performance and characteristics of LC across assessments to further understand LC trajectories. The assessments were conducted over an average of 24 months. The extended duration between the first and last assessment adds depth to the existing literature, by examining whether cognitive impairments persist, worsen or show signs of recovery two years since the first assessment. This timeframe is especially relevant considering that many definitions of chronic illnesses describe symptoms persisting beyond 12 months as indicative of a long-term condition (Airhihenbuwa et al., 2021).

Alongside the cognitive measures captured at each assessment, the studies also tracked symptoms, fatigue levels, quality of life scores and daily functioning. Firstly, the LC characteristics and other measures will be presented , followed by the cognitive functions measures captured.

Characteristics

Symptoms

The most frequently self-reported symptoms at all three assessments were problems with memory, extreme tiredness and problems with concentration, and these self-reports were reflected in performance. The sample at Assessment Three reported more symptoms that the other two samples.

Severity

The Linear mixed models showed that the main effect of Acute Severity only significantly predicted performance on one cognitive measure (Story recall Long Delay) and with daily limitations. However, the effect of Acute Severity was more apparent in the interactions with Fatigue and LC Severity. This provides some evidence to suggest that the severity of the acute infection does not consistently and directly predict long lasting cognitive performance in isolation, but differs when other factors are considered alongside

Zhao and colleagues found that some memory performance was most impaired shortly after infection (Zhao et al., 2022). In contrast participants in the present studies had been living with LC for an average of 44 months. However, given the significant associations with acute severity, alongside the interactions in the LMM, this may provide evidence that acute effects of the Covid-19 are linked to cognitive performance in some tasks. However, the lack of persistent main effects for Acute Severity for all tasks may reflect that initial illness severity is not a robust predictor of long-term cognitive function. Other research has found links between acute illness severity and cognitive outcomes, reporting the severity of acute Covid-19 infection as a significant predictor of cognitive underperformance, particularly in those who had required hospitalisation or medical support. Those with the most severe acute infections (requiring hospitalisation and were put on a ventilator) demonstrated substantial cognitive deficits, in participants who had ongoing symptoms between 1.96 and 9 months (Hampshire et al., 2021). Vannorsdall and colleagues (2022) also reported that individuals who had required intensive care during their acute illness showed long term memory impairments. The present findings do not contradict these earlier studies but instead suggest that acute severity alone may not fully explain the persistence of cognitive impairments in LC, particularly in those several years postinfection. Instead, the interaction between Acute Severity, Fatigue, and LC Severity appears to affect cognitive functioning. A possible explanation into how these factors negatively affect cognitive functioning is the effect they have in combination. For example, as fatigue increased, this may have reduced attention and memory, which coupled with more severe Acute Severity and more severe LC Severity (that appears to lead to ongoing burden), the available cognitive resources to participants may have been reduced.

The LMM results revealed that those with higher LC severity performed poorer on two tasks, Source memory and Word Recognition. LC Severity also predicted a higher total number of daily limitations which suggests that LC Severity variables impact not only cognitive performance but functional impairments.

These findings contrast with those of Zhao et al. (2022) who reported no direct association between LC severity and memory performance. Severity in that study was based on the symptoms participants had, in which the highest reported was 'asymptomatic' (*N* = 39). The authors did recommend future studies to explore the relationship between LC severity and performance which these results directly address. Similar to the present findings, Hampshire and colleagues (2021) discovered that persistent symptoms were associated with more pronounced cognitive deficits even beyond the acute phase.

The three-way interaction captured in the LMM between Fatigue, Acute and LC Severity revealed an interesting and surprising result in that those with higher LC Severity had reduced effects of Fatigue and Acute Severity on their cognitive performance across several tasks. This provides further evidence that LC Severity alone is not a predictor of poorer performance. A possible explanation is that those with higher LC severity may already experience cognitive burden, thus adding factors likes Fatigue or Acute Severity does not further decline performance. In contrast, individuals with lower LC severity may have more room to decline and for this to be detected in their test performance when factors like Fatigue and Acute Severity are added.

The opposite pattern was seen in the three-way interaction for the Source memory task, where pwLC with higher LC Severity scores in combination with High Fatigue and High Acute Severity showed poorer performance. Unlike in other tasks where adaptation may have been associated with less decline in performance, Source memory may be more difficult to strategize for as it relies on hippocampal and prefrontal cortex binding processes (Yonelinas, 2013), thus harder to rehearse compared to other tasks. Remembering contextual source details involves binding processes that are largely automatic and thus harder to use compensatory strategies to substitute. The qualitative narratives also illustrate the difficulty with source memory.

QoL and Fatigue

At all three assessments, pwLC reported significantly poorer QoL scores and higher levels of fatigue scores compared to controls. These two variables consistently significantly correlated at each assessment suggesting a long-lasting relationship in this sample. As reported earlier, extreme tiredness was one of the most frequently reported LC symptoms in the self-report questionnaire and featured heavily within the thematic analysis.

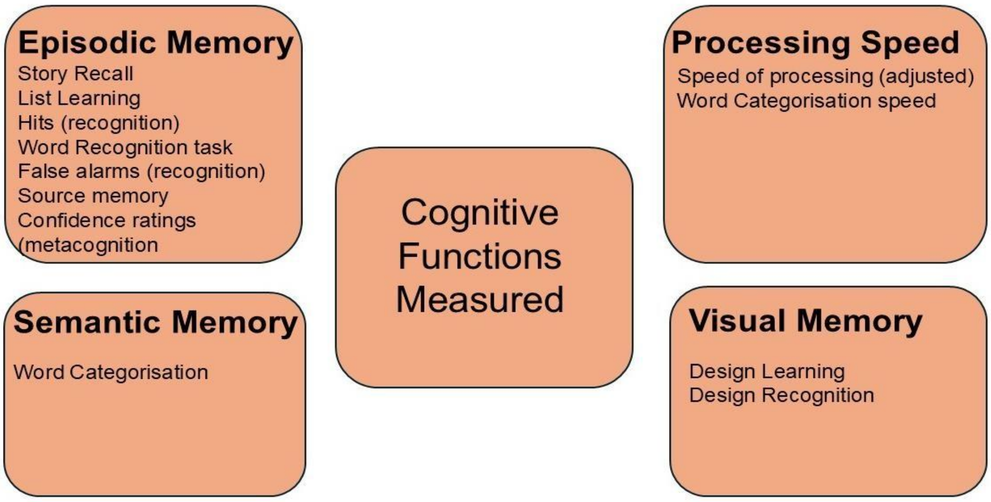
Fatigue scores were lowest at Assessment One and increased over time which again highlights the long-lasting and compounding nature of fatigue for pwLC. The changes in fatigue scores across assessments may explain some fluctuations in performance over time. Fatigue has been shown to negatively affect cognitive functions such as memory, attention and processing speed in pwLC (Agergaard et al., 2023; Graham et al., 2021) and this study supports those findings through longitudinal analyses. Fatigue has been repeatedly identified as one of the most persistent and debilitating symptoms in pwLC that is often resistant to improvement, even when other cognitive symptoms show signs of recovery (Kim et al,. 2023). QoL scores did not significantly change over time, they remained consistently lower than controls, further evidencing the chronic impact of LC on everyday functioning. No main effects nor interactions in the LMM impacted QoL.

Fatigue was a significant predictor of poorer performance in several tasks. The interactions identified between Fatigue, Acute Severity, and LC Severity provide further evidence that the cognitive impact of fatigue is not uniform, but influenced by Acute and LC Severity. It would also be reasonable to suggest that acute and LC severity could be influenced by fatigue levels. In some tasks, the negative effects of fatigue were moderated by LC Severity, while in others those with higher LC performed worst when fatigue was also high. The results within this chapter align with previous research showing that although some individuals with LC report gradual improvement (Davis et al., 2021, Graham et al., 2021), many continue to experience limitations in cognition and function, factors which can directly impair QoL.

Cognitive Functioning

Figure 31 provides a summary of the cognitive functions assessed within this chapter.

Figure 31. Visual summary of cognitive functions measured within Chapter Two



Episodic Memory

Episodic memory is supported by the medial temporal lobe (MTL), particularly the parahippocampal cortices and the hippocampus (Dickenson & Eichenbaum, 2010). Given that these regions support the ability to encode and retrieve memories

(Dickenson & Eichenbaum, 2010), episodic memory could be vulnerable to LC related changes, as they are in hippocampal patients (Addante et al., 2012). Within this chapter, episodic memory was measured in a variety of different tasks and the results suggest episodic memory distribution in pwLC with evidence to suggest some recovery over time but sustained impairments in verbal recognition.

The LMMs revealed significant improvement over time in all three recall conditions suggesting improvements in verbal memory. This aligns with research reporting verbal memory improvement over time in some pwLC (Cecchetti et al., 2022; Ferrucci et al., 2021), but contrasts with findings that reported sustained deficits in immediate recall up to 12 months post-infection (Méndez et al., 2021).

Story Long Delay recall was more strongly affected by main effects (Assessment, Fatigue and Acute Severity) and interaction effects (Fatigue x Acute Severity, Fatigue x LC Severity and Fatigue x Acute Severity x LC Severity) in the LMM than any other cognitive variable. This provides evidence to suggest verbal memory is sensitive to Fatigue, Acute and LC Severity. However, there was no evidence of accelerated long-term forgetting across assessments suggesting that consolidation mechanisms were intact despite reduced recall.

Severity, Fatigue x LC Severity and Fatigue x Acute Severity x LC Severity) in the LMM than any other cognitive variable. This provides evidence to suggest verbal memory is sensitive to Fatigue, Acute and LC Severity. However, there was no

evidence of accelerated long-term forgetting across assessments suggesting that consolidation mechanisms were intact despite reduced recall.

List Learning performance fluctuated across assessments, with only A6 (recall after a distractor list) showing a significant improvement over time, suggesting reduced susceptibility to interference over time. However, performance was consistently poorer than normative data and controls at Assessments One and Three, with relative improvement at Assessment Two. No significant interaction effects were found for List Learning in the LMM suggesting this task was less susceptible to Fatigue, Acute and LC Severity. Given that participants may have suspected the long-delay task as they had completed this twice previously, the lack of improvement for List Learning recall over assessments is further evidence of impairment.

The highest prevalence of cognitive impairment, scores below the 2nd percentile rank, was observed in the Word Recognition task at all assessments. PwLC performed significantly poorer than both the control group and normative data indicating verbal information is challenging for pwLC and aligns with previous research that reports verbal recognition memory as one of the most impaired cognitive domains in pwLC (Becker et al., 2021; Graham et al., 2021).This might reflect disruption in memory consolidation or retrieval mechanisms (Dickenson & Eichenbaum, 2010). For pwLC in day-to-day functioning, this might manifest as difficulty following conversations or recalling verbal instructions. However, the LMM showed an improvement over time. A possible explanation for these improvements may reflect practice effects as the same tasks were completed across the three assessments, however practice effects were controlled for in the second assessment by using Form 2. In addition, despite improvements, people were still performing worse than controls for this task.

In the BMIPB-II Word Recognition source task (identifying if a word was from List A or List B), performance was poorer than normative data and controls at Assessment One and Assessment Two but improved over time as shown in the LMM results. Similarly, Source memory in the Design Learning task initially showed performance poorer than the normative data but this was no longer evident at Assessment Two and Assessment Three. The LMM confirmed improvement over time and no pwLC showed impairment in this task by Assessment Three. The results suggest that Source memory impairments in pwLC may differ by task, and improvement over time may suggest that source memory is less vulnerable to LC impacts.

In contrast, pwLC performance in the self-guided source task (identifying whether the item was from the alive or manmade list) was not significantly different to controls at any assessments. However, the LMM showed that Assessment, Fatigue, Acute and LC Severity significantly predicted source performance.

Across all three assessments, pwLC made fewer correct recognitions (hits) than controls, however there was no main effect of time in the LMM. In contrast, false alarm rates were lower than controls at Assessment One, then not significantly different at Assessments Two and Three. These patterns suggest task-specific variability at each assessment (i.e. no change in hits over time but changes in false alarms over time) and cautious responding. Item memory showed no significant differences between pwLC and controls and no change over time. However, performance was significantly influenced by fatigue, and a three-way interaction with Acute and LC Severity. This contrasts with results by Addante and colleagues using the same task who found hippocampal patients to be impaired compared to controls in item memory (Addante et al., 2012).

PwLC demonstrated lower confidence in correct recognitions (hits) and overall item recognition. No significant changes were observed over time. However, the only main and interaction effects emerged in high-confidence False Alarms, where fatigue and its interaction with LC Severity predicted performance. This suggests that fatigue may play a role particularly when distinguishing familiar distractors from true memories. The impaired high-confidence responses to item memory aligns with research by Addante and colleagues (2012) on hippocampal patients.

Episodic memory was frequently impaired in pwLC across multiple tasks which aligns with previous research that reported episodic memory as one of the most frequently affected domains in pwLC (Becker et al., 2021; Zhao et al., 2022). Research has suggested that episodic memory difficulties in pwLC may reflect disruptions to encoding, consolidation and retrieval processes. These could potentially be linked to hippocampal and medial temporal lobe vulnerability following

Covid-19 (Becker et al., 2021; Zhao et al., 2022). The results extends literature by suggesting that episodic memory impairment in pwLC may not be static. Improvements observed on some episodic memory tasks are consistent with prior longitudinal research indicating partial cognitive recovery over time in subsets of pwLC. However, the persistence of impairment across other measures indicates that recovery may be task dependent.

Semantic Memory

Semantic categorisation appeared intact in pwLC even at the first assessment. Performance on the Word Categorisation task did not significantly differ from controls at any Assessment, except for a temporary decline at Assessment Two. However, the LMM revealed no significant longitudinal changes indicating that semantic memory remained stable. This preservation contrasts to the examiner-administered results whereby participants consistently performed poorer than controls, and may provide evidence that performance may be task specific. This aligns with previous research suggesting that semantic memory is less susceptible to acute cognitive disruption particularly in the anterior temporal lobes (Patterson et al., 2007; Ralph et al., 2017).

Visual Memory

Visual memory outcomes showed stability across assessments compared to verbal memory measures. Performance on the visual memory tasks did not significantly differ from normative data. The longitudinal analyses revealed that pwLC improved over time which may suggest that visual encoding and retrieval processes are less vulnerable in pwLC. A further explanation could be that the task used to examine visual memory may have required less cognitive demand than the other tasks therefore reducing cognitive fatigue and burden. Supporting this, for visual memory performance in the normative data set, participants scored on average 57% correct (40 out of a possible 70 points) compared to an average 50% correct on the Word Recognition task (15 out of 30 possible points). This may indicate that for healthy population performance on the visual BMIPB-II task is typically better than performance of verbal recognition. However, this is not true for all tasks. In list learning the normative data score on average 73% correct (55 out of a maximum of 75), whereas pwLC perform poorer. It could also be that this task is less vulnerable to practice effects. Variability with deficits across cognitive domains have been previously reported in pwLC (Hampshire et al., 2021), whereby larger deficits were observed in more complex tasks such as verbal analogies and the tower of London task compared to more basic tasks.

While scores did not differ from the normative data, some pwLC showed impairments in these tasks, albeit the impairments for visual memory were the least prevalent. This aligns with research showing that visual memory can be affected in some individuals with LC up to 12 months following an acute infection though usually to a lesser extent than verbal memory (Delgado-Alonso et al., 2022; S. Zhao et al., 2022). However, research by Guo and colleagues (2022) found no significant group differences for visual memory using the Mental Rotation Test, suggesting that task modality may influence performance. This may explain why visual memory is largely preserved compared to other cognitive domains. Furthermore, neuroimaging studies have also shown that posterior cortical regions, including the parietal and occipital lobes involved in visual processing may be less affected by Covid- 19 related inflammation compared to other structures (Douaud et al., 2022; Hosp et al., 2021).

Processing Speed

The results again revealed different pattens in processing speed. For Word Categorisation speed that was captured during the self-guided tasks, reaction time did not differ from controls, and no significant changes were seen over time. These results align with research that also found no differences in processing speed between pwLC and controls (Zhao et al., 2022) but contrasts with previous research who reported reduced processing speed in pwLC (Hampshire et al., 2021). However, it is acknowledged that processing speed is not the same as reaction times.

In contrast, the examiner administered SOIP task scores were significantly poorer compared to the normative data at all assessments. However, the LMM indicated significant improvements over time. These findings are consistent with previous research reporting impaired processing speed in pwLC (Delgado-Alonso et al., 2022; Herrera et al., 2023; Krishnan et al., 2022).

A possible explanation for this different pattern may be a result of the task type. Examiner-administered tasks may have placed greater cognitive demands and required sustained attention compared to the self-guided tasks, which were shorter in duration to complete, making them more sensitive to subtle impairments. Furthermore, neurobiological models have suggested that the hippocampus, which is thought to be disrupted from neuroinflammation during Covid-19 infection (Hampshire et al., 2024), may also contribute to speed of processing (O’Shea et al., 2016; Toepper et al., 2010).This could offer a potential neurobiological explanation for the impaired processing speed in more demanding tasks in pwLC.

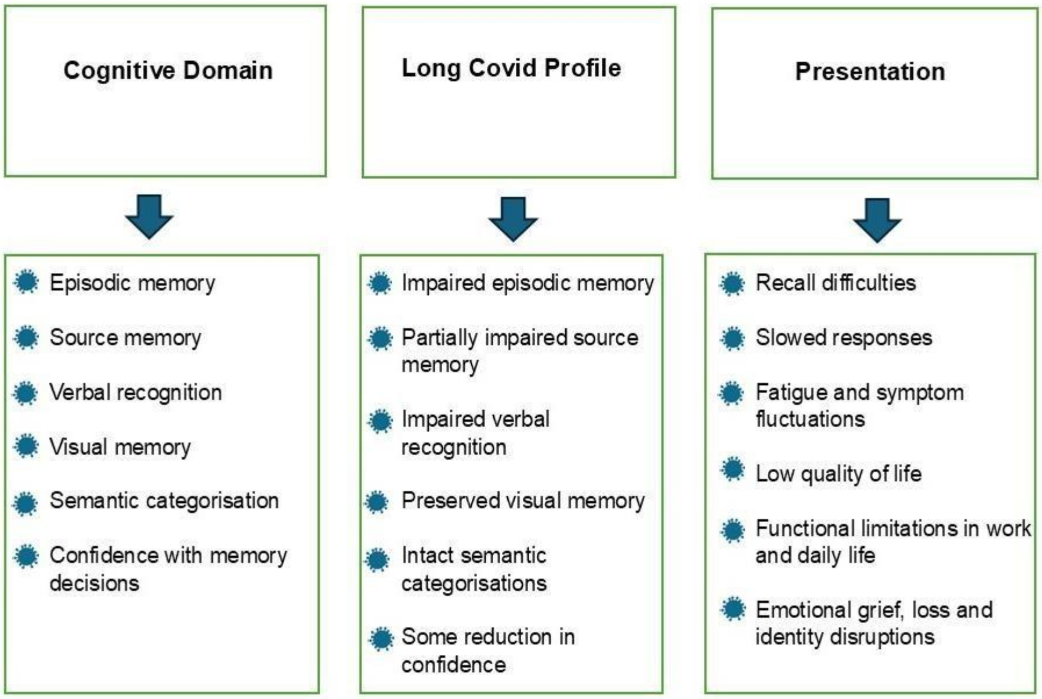
Daily Functioning

The daily limitations statement that had the highest percentage of participants at all three assessments was the one indicating that pwLC were limited in their everyday life activities due to symptoms, pain, depression or anxiety but they were able to care for themselves. This response was reported by 81% of participants at Assessment One, 59% at Assessment Two and 67% at Assessment Three, making it the most frequently chosen option at each assessment.

The LMM revealed that daily limitations were predicted by higher LC severity scores, (i.e. the worse the LC the more daily limitations). However, daily limitations did decrease across assessments which is promising. One study tracked participants for two years post-infection and found that LC symptoms peaked around six months and often caused activity limitations, with some individuals not returning to their preCovid-19 health after 24 months (Demko et al., 2024). Similarly, research indicated that 38% of patients experienced LC symptoms persisting for an average of 22.6 months, with fatigue and cognitive difficulties being most prevalent (Helmsdal et al., 2022).

Based upon the results captured in this chapter, a behavioural presentation of Long Covid is suggested in Figure 32.

Figure 32. Behavioural presentation of Long Covid



In summary, the data collected during this chapter provides evidence that cognitive performance is impacted by LC and this was evident in individuals who have been living with LC for on average five years. While some tasks showed improvements, others remained impaired. Despite some improvements, the total number of impairments did not reduce over time, which suggests that LC cognitive impairments are long lasting. However, the reduction in daily limitations despite these cognitive impairments supports the narrative from some participants towards adaptation and coping. Interactions between fatigue, acute and LC severity demonstrated the impact of those as a predictor of cognitive impairments. Support and interventions to target fatigue management in pwLC could positively influence cognitive functioning. The unchanged QoL scores over time are another factor which illustrate the complex, non-linear recovery trajectory for pwLC.

The results presented within this chapter draw some several novel and important contributions to LC literature. There is evidence that LC is associated with sustained cognitive impairments and functionality. The longitudinal design provides evidence that impairments can persist for up to five years post-infection. The focus on memory functions allowed for some conclusions to be drawn into which memory systems appear to be most vulnerable to LC, that are illustrated in Figure 33. The results are relevant to healthcare providers as they illustrate the need for more inclusive and responsive healthcare that recognises the complexity of LC and allow the voices of those living with it to be heard. Sensitive cognitive screening should be completed in a timely manner to ensure supportive strategies are available for pwLC.

The knowledge obtained throughout these studies, informed the development of further studies that are presented in the next chapters. Qualitative data is analysed in the following two chapters to provide lived experience perspective. Furthermore, the memory impairments identified within this chapter led to the design of a study protocol for an electroencephalography (EEG) study, which aims to delineate the cortical dynamics of memory encoding and retrieval processes in pwLC (Chapter Five).

Chapter Three: Qualitative Survey Responses

Introduction

The chapter presents the findings from a thematic analysis conducted on the open-text responses recorded on a survey completed by participants during Assessments One, Two and Three. These responses provided qualitative insight into the lived experiences, a deeper understanding of the personal implications of living with LC. While the quantitative data from the cognitive assessments and surveys in studies one to three delineate cognitive performance, the qualitative responses add lived context to these findings. Collecting qualitative responses at the three assessments, enabled exploration of how lived experiences may evolve over time and allowed the identification of ongoing concerns. By exploring the results from three cognitive assessments with self-reported QoL and fatigue measures, alongside longitudinal analyses and qualitative responses, this chapter aims to provide further understanding of the impact of LC on both memory and functional outcomes and contribute to a more comprehensive understanding of the effects of LC.

Survey Aims

This aimed to give voice to participants and their lived realities, to aid in understanding the enduring and multifaceted impact of LC. By using mixed methods, it was aimed to achieve a more nuanced understanding. By including the personal narratives of those directly affected, this study aimed to capture the lived experiences of pwLC, from their personal, self-reflexive accounts.

While quantitative measures such as cognitive assessments provide critical insights into the measurable effects of the illness, they often fail to capture the emotional, psychological, and social dimensions of living with a chronic, poorly understood condition and, unlike quantitative data, which typically seek to explain behaviour through statistical patterns, qualitative data provides a rich, contextual insight into how participants make sense of their world (House, 2018). Capturing the lived experiences of individuals living with chronic illness is vital to aid understanding of how patients' lives can be improved and exploring support for them moving forwards (Rapport et al., 2015).

Methodology

Qualitative Data

Qualitative data collection offers opportunities to gain a deeper understanding of a problem by interacting and communicating directly with participants (Denzin & Lincoln, 2008). Qualitative research has numerous benefits including the ability to generate rich descriptions of the participants' lived experiences, thoughts and feelings (Tashakkori & Teddlie, 2003b). In this chapter qualitative analysis is used to supplement the quantitative data from the previous chapter, from survey responses to include lived experiences. Additionally, qualitative data is covered in Chapter Four. These are presented separately as the two data sets have different participants. The qualitative data were analysed using thematic analysis and followed the six phases (Braun & Clarke, 2006) which can be seen in Table 21.

Table 21. Six phases of thematic analysis

Phase	Description of process
1. Familiarizing yourself with your data	Transcribing data, reading and re-reading the data, noting down initial ideas
2. Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
3. Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme
4. Reviewing themes	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis
5. Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme
6. Producing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Thematic analysis is commonly used within mixed methods research designs (Tashakkori & Teddlie, 2003) and has advantages over other qualitative methods, including the accessible and flexible approach to analysing qualitative data, that can be applied in a range of epistemological approaches (Braun & Clarke, 2006). It allows the researcher to take an active role in identifying themes and purposely select themes of interest, compared to discourse analysis whereby themes ‘emerge’ naturally from the data, minimising the interpretation of the researcher (Singer & Hunter, 1999). Minimising versus maximising the interpretation of the research could be both a strength and a limitation. For the purpose of this research, researcher maximising was deemed appropriate to ensure all potential themes could be explored.

Participants

Participants who took part in Assessments One, Two and Three in Chapter Two were included in this thematic analysis. Participants included in this analysis completed at least one open-ended response in the Covid-19 survey administered during one or more of the three assessment periods.

The inclusion of participants from all assessments allows for a longitudinal understanding of how experiences of LC may evolve or persist over time, complementing the quantitative findings. The demographics of participants who provided text responses at shown in Table 22

Table 22. Participant demographics for open-ended responses across Assessments One to Three

Demographics	**A1**	**A2**	**A3**
Sample size	*N* = 63	*N* = 22	*N* = 22
Sex			
Male	10 (16%)	4 (18.18%)	4 (18.18%)
Female	53 (84%)	18 (81.82%)	18 (81.82%)
Age in years *M (SD*)	45.64 (11.92)	49.28 (13.23)	49.57 (8.27)
Country			
United Kingdom	*N* = 49 (77.78%)	*N* = 14 (63.64%)	*N* = 17 (77.27%)
United States of America	*N* = 8 (12.7%)	*N* = 5 (22.73%)	*N* = 4 (18.18)
Norway	*N* = 2 (3.17%)	*N* = 1 (4.55%)	*N* = 1 (4.55%)
Brazil	*N* = 1 (1.59%)	*N* = 1 (4.55%)	-
Poland	*N* = 1 (1.59%)	*N* = 1 (4.55%)	-
Spain	*N* = 1 (1.59%)	- -	-
Egypt	*N* = 1 (1.59%)		

Materials

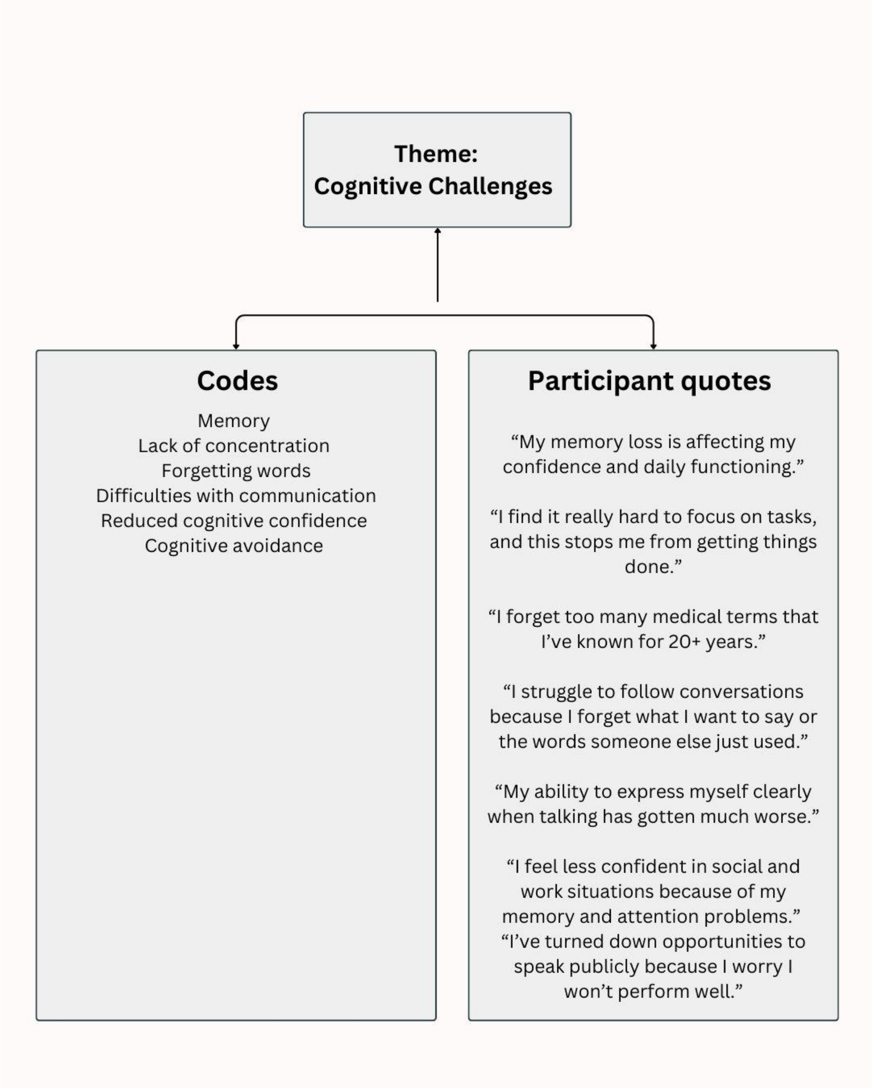
Participants were asked to complete a Covid survey during Assessment One and this was repeated in Assessments Two and Three in the previous chapter. This survey consisted of 16 questions related to the Covid-19 virus including symptoms, both during the infection and longer-term symptoms, any diagnoses participants may have received and any medical aids or treatments they have used to help with symptom management, including the use of medication and social prescribers. The data from this survey were analysed in Chapter Two, with the exception of the question “Is there anything else about your Long Covid symptoms or experience you'd like to share?” which is analysed qualitatively within.

Results

To explore and interpret these narratives, thematic analysis was conducted in line with Braun and Clarke’s six-phase framework (outlined in Table 2). This approach is widely recognised for its flexibility and depth, making it well-suited to analyse qualitative data derived from personal experiences as discussed in the methodology section. Each of the three qualitative datasets from Assessments One, Two, and Three was analysed independently to allow for the emerging themes within each assessment. Following the separate assessments, the results are then synthesised together and a conceptual model is presented.

During phase two of Braun and Clarke’s framework, the process of initial coding began. Each open-ended response was read in detail, line by line, and systematically coded to capture key features that reflected participants lived realities of LC. This inductive coding process allowed themes to emerge directly from the data. The emphasis was placed on remaining close to the language and intent of participants, ensuring that their voices guided the analytic process. As the coding progressed commonalities became apparent revealing shared experiences as well as individual differences in the ways people were navigating life with LC. These initial codes were then organised into categories and refined through iterative review. The resulting themes form the basis of the qualitative results presented in this chapter, providing an account of the ongoing impact of LC. An example of a coding tree is shown in Figure 33.

Figure 33. Example coding tree



Although responding to the open-ended question was optional, a substantial proportion of participants chose to contribute indicating a desire to be heard and to share their perspectives. Eleven participants completed the open text response at all three time points. Out of a total of 68 participants who took part in the Covid-19 survey during Assessment One, 63 participants (92%) provided a written response to the open-ended question. This high response rate indicates a strong willingness among participants to share their personal reflections. The response rate to the question was lower at Assessment Two (*N* = 22, 47.8%) and Assessment Three (*N* = 22, 56%). The volume and depth of these responses resulted in a valuable dataset, capturing a broad range of lived experiences that extend well beyond the constraints of numerical data. The description of the data collected from survey responses at all assessments can be seen in Table 23.

Table 23. Number of words used on the survey responses at Assessments One, Two and Three.

	Assessment One	**Assessment Two**	**Assessment Three**
Number of words used in the open-ended responses	Min 3 Max 97 *M* = 32.71 *SD* = 25.42	Min 3 Max 128 *M* = 48.31 *SD* = 29.70	Min 6 Max 213 *M* = 66.00 *SD* = 58.30

Within this section, the results of the analyses of each of the three qualitative datasets from Assessments One, Two, and Three are presented within their respective time points and the findings are then discussed as a whole to provide a richer and more dynamic understanding of how participants experiences evolved over time. The themes that will be discussed are illustrated in Figure 34.

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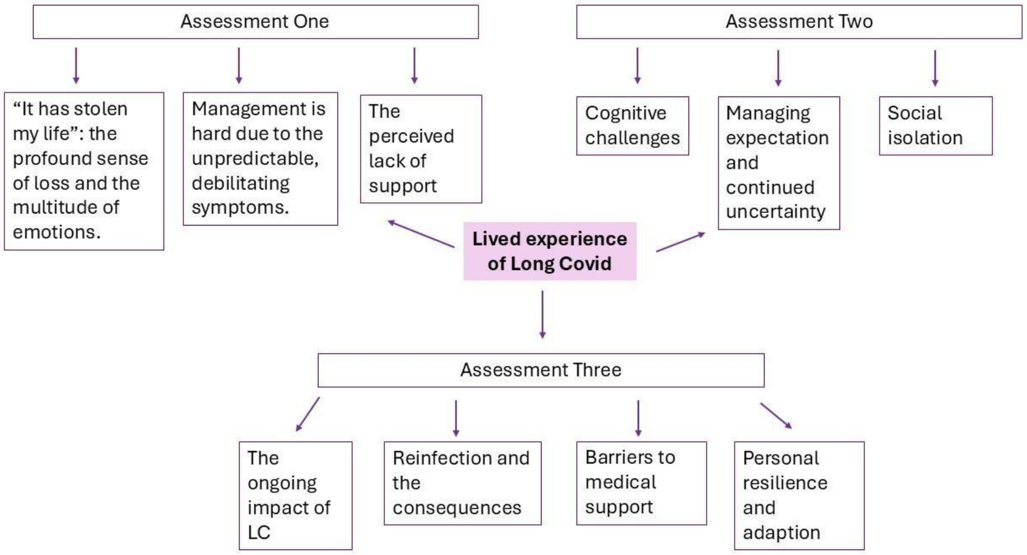
Figure 34. Overview of themes at Assessment One, Assessment Two and Assessment Three



Assessment One: Thematic Analysis

Three themes were generated that capture experiences reported by participants at Assessment One. The first theme, "It has stolen my life" – the profound sense of loss and the multitude of emotions, reflects the ongoing disruption to identity as a result of LC. The second theme unpredictable debilitating symptoms, highlights the challenges of navigating daily life while living with fluctuating symptoms. The third theme "perceived lack of support", captures participants' frustration and distress in relation to perceived insufficient medical and societal support. These themes help to build a rich picture and may aid understanding of the long-term impact of LC on participants' wellbeing and quality of life. During Assessment One, participants had been living with LC for an average duration of 24.68 months (*SD* = 11.00).

Theme One: “It has stolen my life”; The profound sense of loss and the multitude of emotions pwLC are facing.

This theme captures the sense of loss and grief experienced by pwLC. Beyond dealing with the physical manifestations of LC, participants reported various difficulties with their sense of identity. The responses illustrated a multitude of emotions including grief for the loss of their former selves, anxiety about the future and feelings of isolation due to the lack of understanding. Many participants shared their perspective into the ongoing struggles they face daily, which gave insight into how deeply LC impacted their wellbeing and emotional resilience.

A prevalent loss was employment. Many participants shared how severely LC had impacted their work with several having to give up their jobs entirely, while others reported struggling to perform at their pre-Covid capacity. The emotional and psychological toll of being unable to continue working or maintain their previous productivity was evident throughout the responses. For many, the decision to give up work was driven by the physical and cognitive limitations caused by LC. As one participant expressed, their limited energy was entirely consumed by work, leaving no capacity for any other aspects of life, further exacerbating feelings of loss.

> “*It has led to me giving up work as found all my limited energy went on working and none left for family (or fun things)”* (pwLC4)

Despite efforts to continue working with adjustments, some participants reported that the persistent symptoms of LC made it feel impossible to return to their previous performance levels: *"I am unable to perform at work as well as I could before, even with reasonable adjustments*" (pwLC22). The inability to manage the demands of work eventually forced others to resign. One participant shared how they had become almost housebound due to the severity of their symptoms and therefore were unable to work in any capacity:

> "*I had to resign from my job due to not being able to cope with my symptoms anymore, and since then, have been mostly house / bed bound*" (pwLC34).

This not only led to financial instability but also deeply affected their sense of purpose and self-worth. One participant stated, the debilitating nature of the illness led to an unavoidable exit from their job: *"It's just so debilitating, I had to give up work"* (pwLC27). This narrative was echoed by another participant who described how their employment was lost due to the ongoing impact of LC "*I lost my employment due to Long Covid"* (pwLC32). Several participants explicitly shared how their mental health had been negatively affected by their inability to work and the associated struggles: "*It has left me financially broken as well as physically and mentally"* (pwLC37). The profound impact on individuals' ability to work and their self-image has been reflected in previous accounts by pwLC (Lerer et al, 2022).

The sense of loss expressed by participants extended beyond their employment, affecting lots of aspects of their lives, from their independence to their ability to engage in activities they once enjoyed. The disruption to daily life became evident in the personal accounts of individuals who found themselves unable to complete basic tasks that they had previously managed with ease. This loss of autonomy caused frustration and emotional distress, especially as many participants had to rely on others for help. Participants shared the practical difficulties they faced as they struggled to maintain their homes and personal lives, expressing the emotional toll of becoming dependent on others. One participant reflected on the need to hire help for basic tasks due to their physical limitations:

> "*I have had to pay for someone to clean my home and tend to my garden because I am unable to keep up. My partner also has to help a lot more*" (pwLC53).

Others spoke of their inability to drive or perform other activities they once took for granted. The restriction in their daily routines made it difficult for them to experience the sense of freedom and independence they had enjoyed before:

> "*I am unable to drive etc*." (pwLC32), *"I am unable to do any other activities and am often unable to complete tasks like housework*" (pwLC65).

Many described a constant cycle of mastering a particular task only to face new challenges that left them feeling helpless again. This struggle contributed to their sense of frustration and further diminished their quality of life:

> "*(...) but it seems like I master a task and new problems come and I lose ground need more help to shop and do things in the community"* (pwLC54).

For some, the physical toll of LC was so debilitating that even the simplest of tasks became difficult "*some days I'm too exhausted to even shower"* (pwLC36). The emotional impact of losing the ability to engage in activities they once loved was also deeply felt. For some, the physical limitations imposed by LC were so severe that they could no longer engage in activities they once enjoyed

> *"Long Covid has completely changed my life"* (pwLC 37), *"I have had to stop riding a motorcycle and doing some of the things I love because of the attack on my body and brain*" (pwLC54), "*It's severely impacting my life"* (pwLC 20*). "I've gone from being very active and doing high level gymnastics to now being almost a full-time wheelchair user not being able to endure going out for very long"* (pwLC 17).
>
> The cognitive challenges participants faced, including memory difficulties, also had a psychological impact. One participant described how initially, the inability to recall words and focus led to increased anxiety and frustration making their symptoms worse
>
> "*to start off with I got very stressed not being able to remember words which made it worse. It worried a lot of people, now the less I worry the easier it is"* (pwLC25). The emotional effects were evident *"I try to stay positive, but I wish I could have my old life back*"(pwLC53) and "*I feel I have a lot less get up and go. I feel a bit broken from it*" (pwLC52).

Others echoed a sense longing for their pre-Covid life, wishing for a return to the health and energy they once had. These narratives reveal how the combination of physical, cognitive and emotional challenges posed by LC can severely affect not just participants financial stability but their psychological resilience as well.

Participants described how LC had affected their cognitive functioning, with many noting the loss of abilities they may have once taken for granted: "*I lost the ability to multi-task*" (pwLC11). "*Just changed the way I do things"* (pwLC25). "*I feel that covid has impacted on all aspects of my life and health"* (pwLC8), which was echoed by pwLC who declared 'I can't cope with multiple inputs', which was a theme on previous research (Callan et al., 2022). The emotional and psychological effects of LC were further reflected in the frustration and sadness of not only the physical toll but the transformation of their lives in ways they had not anticipated. These reflections underscore the ongoing grief that pwLC face as they try to cope with the limitations and uncertainties of their illness. Loss and frustration resulting from limitations with activities of daily living, alongside the challenges of living with the unpredictability of symptoms, have also been observed in patients living with chronic pain (Harris et al., 2003; Mason et al., 2004). The sense of loss was evident in the profound changes to their identities and daily routines. For many participants, the longing for their pre-Covid lives was linked to grief, frustration and sadness as they navigated the ongoing uncertainties:

> "*It has completely uprooted my entire life"* (pwLC36) and *"(...) but the psychological challenges of having Long Covid are huge - grief, loss, fear - which don't necessarily fit into diagnoses of anxiety or depression*" (pwLC3).

The grief for their lost selves was expressed through the phrase, "*I just want my old life back*" capturing the frustration and sadness of loss of former self. Unfortunately, the experience of loss is common for those who experience chronic illnesses

(Gordon & Benishek, 1995). This account was echoed by other participants, who longed for the independence they once had:

> *“I cannot work, socialise or walk my dog, it has stolen my life”* (pwLC68), *“I was very healthy before and energetic*” (pwLC9), “*Basically, since catching covid, I have been housebound except for hospital/GP visits”* (pwLC70), “*I've lost my job, I hardly leave the house, I'm currently fighting for disability [benefits]”* (pwLC36).

The unpredictable and nonlinear recovery from LC appeared as a source of frustration for participants. Many expressed disappointment that improvement was not consistent and that setbacks were frequent, often exacerbated by additional illnesses or complications *“although gradually improving this has not been a linear improvement [there have been] setbacks with further illnesses*” (pwLC18). The unpredictability in the recovery process created a sense of uncertainty and hindered individuals’ ability to plan for the future, which has been discussed in other pwLC research(Callan et al., 2022; Kingstone et al., 2020; Lerer et al., 2022). Several participants reflected on the challenges of distinguishing between the ongoing effects of LC, and other emotional or psychological factors, such as depression, which could be exacerbated by prolonged isolation and illness. The struggle to determine whether symptoms related to LC or the emotional toll of being unwell for extended periods added to the complexity of their recovery journey:

> *"(…) difficult to tell if concentration problems are from neurological issues or just result from depression at being isolated and sick for nearly a year"* (pwLC56).

This theme demonstrates how LC causes widespread disruption in many aspects of everyday life and reflects the impact of a chronic illness that is not only physical, but it is reducing independence, limiting social interactions and affecting employment and much more. LC is leading to people feeling profoundly changed, broken and a different person to the one they were before.

Theme Two: Unpredictable debilitating symptoms

Participants described the unpredictable and fluctuating nature of LC symptoms and how these impact their daily lives. These symptoms often leave many participants struggling to perform everyday tasks. Furthermore, the variability of symptoms makes it difficult to plan for the future or maintain a sense of stability. In addition to cognitive issues, some participants reported other distressing physical symptoms which were severe enough to require medical investigations. These symptoms, combined with fatigue, create a complex and overwhelming challenge for pwLC to navigate daily life:

> "*I also suffer from bad headaches since having Covid-19, I also suffered badly with pains in one side of my face which required an MRI"* (pwLC5).

Participants described the overwhelming mental fatigue that comes with LC, this exhaustion is often accompanied by cognitive difficulties that further hinders participants ability to engage in activities of daily living.

> *I am exhausted, my brain just doesn't work, I struggle to process conversations"* (pwLC35), "*I find the worst part of it my brain, the way my brain has responded and how I cannot beat the tiredness*" (pwLC31) "*cognition affects my ability to work efficiently*" (pwLC46)

An observation in many of the participants' narratives is the feeling of fatigue being distinct from what they had experienced before

> *"I think the best thing to describe the fatigue is that I feel I have a monster inside me sucking my energy and have to fight against it. Unfortunately, the physical tiredness creates mental tiredness too*" (pwLC24).

The unpredictability of symptoms also contributes to heightened psychological distress. Many participants shared that their symptoms fluctuated not just from day to day, but sometimes hour to hour. This constant variation creates a sense of instability and uncertainty, making it difficult to plan daily activities or even predict how they will feel in the near future:

> "*Symptoms fluctuate from day to day*" (pwLC66). "*My long-lasting symptoms can vary from mild to severe over the course of a few days or weeks*" (pwLC22). "*Covid has stopped my life in its tracks and it's so unpredictable,*

> *never know what each day / hour brings"* (pwLC9). "*Symptoms are very changeable; every day is different and unpredictable"* (pwLC21).

The unpredictable and fluctuating nature of symptoms also have significant implications for participants' ability to engage in activities. Participants mentioned that they had to pace themselves carefully and even short periods of activity could leave them bedridden. This constant need to adjust and make last minute decisions about what they could or could not do further exacerbates the emotional burden:

> "*The symptoms are variable not only over the course of a day but every day, which makes planning very challenging. If I have to be out in the car one day (even for a short space of time, 20 minutes), I have to remain at home the next day. Most of my life is spent in the home"* (pwLC61).

For some, despite attempts to adapt and manage the illness, there is a sense of nearing their limits, physically and emotionally. This overwhelming sense of limitation, combined with the unpredictability of symptoms, left many feeling as though they have no clear path to improvement or a return to their previous quality of life: "*I have managed to adapt my life to compensate for my illness, but I am very close to my limit"* (pwLC65). "*The symptoms are unpredictable, so management is incredibly difficult*" (pwLC37). Some participants expressed frustration, leading to a sense of resignation and hopelessness: "*Nothing so far helped me with my long covid symptoms, I have been suffering from it"* (pwLC2).

The fluctuating, unpredictable nature of LC symptoms emerges as one of the most significant barriers to recovery for many participants. Not only does it complicate the day-to-day management of the illness, but it also impacts on the participants’ sense of stability and control, contributing to both physical and psychological distress, as it does in patients with myalgic encephalomyelitis / chronic fatigue syndrome (ME / CFS) (Fennell et al., 2021). A common theme across participant responses was the necessity of establishing new routines and adopting strategies to manage their symptoms. This included careful pacing to avoid overexertion, a key factor in preventing symptom flare-ups commonly referred to as "crashes." The experiences shared by participants highlight the challenges of balancing activity levels in a way that prevents worsening of symptoms. Participants described how overdoing it or engaging in activities that they previously enjoyed often led to a relapse in their symptoms. One participant noted the nature of their symptoms, where periods of feeling better were followed by crashes: *“I tend to have what I call 'flare ups' so although I am a lot better than I was, if I overdo it then the long covid symptoms start again, especially the fatigue and shortness of breath”* (pwLC47).

This was also echoed by another participant, who described how they experienced periods of relative stability, followed by sudden and unpredictable decline in their wellbeing *“I have periods when I feel better, then I crash again”* (pwLC49). The temporary improvement followed by ‘crashes’ highlights the ongoing unpredictability of LC and therefore the challenges for participants to make plans or commit to daily routines. These fluctuations may not only affect physical health but may also contribute to frustration, as participants may feel caught between moments of hope and discouragement, “*Nothing so far helped me with my long covid*” (pwLC2). To help manage symptom fluctuations, one participant highlighted their use of the *Visible* app, *“I use the Visible app to help pacing and monitor my symptoms”* (pwLC 50). This helps to gain insights into their physical limits and tailor activities to avoid exertion. However, the emotional and physical strain of balancing activities remains challenging for some pwLC.

An additional layer of complexity in managing LC is the potential for reinfection with Covid-19, which many participants reported as having a significant negative impact on their recovery. For some, the reinfection caused them to regress in their recovery journey, exacerbating symptoms that had previously begun to improve or stabilise. The setbacks caused by reinfection added to the unpredictability and frustration experienced by participants, making it even more challenging to manage their symptoms and make progress. Participants shared their experiences of how reinfection set them back in terms of physical and cognitive symptoms. One participant described the devastating impact of reinfection after they had started to feel like they were recovering from their initial infection:

> “*After my first infection, it took almost a year, but I was starting to finally bounce back. Once I was reinfected, I was back to square one and feeling fatigued, breathless, vocal issues etc*” (pwLC26). Another participant reported a worsening of cognitive symptoms following reinfection “*after reinfection my memory and concentration got worse*” (pwLC30).

Additionally, reinfection in some cases led to a prolonged period of worsened symptoms which lasted for some months and continued to affect their overall wellbeing. One participant reflected "*these symptoms then worsened for six months prior to a second covid infection and symptoms have been at their worst since this*" (pwLC64). This suggests that the impact of reinfection can have long-lasting effects that may hinder recovery and demonstrates the challenge of making progress, only to have it undone by reinfection. Due to this, the fear of reinfection may contribute to the stress of managing an illness like LC, as the prospect of worsening symptoms and potential setbacks may impact recovery trajectories.

In addition to dealing with the unpredictable and debilitating symptoms of LC, many participants reported that pre-existing health conditions had worsened since contracting Covid-19. Others described the onset of new medical conditions postinfection, adding further complexity to symptom management and significantly increasing the overall burden from ill health. These comorbidities not only intensified the physical challenges participants faced but also heightened psychological stress. For example, participants noted how chronic conditions, had accelerated or worsened since their infection with Covid-19:

> "*The reactive arthritis accelerated the progression of osteoarthritis"* (pwLC6), "*I had a hearing issue that I use hearing aids for, but it had become worse since Covid"* (pwL15). Another participant linked the impact of Covid-19 with the exacerbation of Epstein Barr Virus (EBV) symptoms, which added another layer of health complexity: *"Since I tested positive for Epstein Barr, I cannot*

> *help but feel that Covid / the vaccine made the effects of EPV even worse*". (pwLC28).

Several individuals described a general deterioration in their health and failing to return to pre-Covid levels:

> *"I have had my lung health, anxiety, arthritis, and hay fever all deteriorate over the Covid period and never return back to the pre-covid levels"* (pwLC38).

The ongoing struggle to recover from LC and manage pre-existing conditions was also reflected in participants' surprise at the length and unpredictability of the recovery process:

> "*I didn't quite realise how long the path to recovery would be and the impact on my already existing health conditions"* (pwLC57).

Furthermore, some participants reported developing entirely new conditions that they had never experienced before:

> *"I got costochondritis and also hypermobile ribs which I had never had before. I also now struggle with spelling which was never a problem"* (pwLC45)

There was narrative to further demonstrate the psychological impact on individuals with LC as well as the impact of unpredictable symptoms on wellbeing. For many, the fluctuation in physical symptoms, often with no warning or clear triggers, has exacerbated feelings of distress and anxiety. Beyond the fatigue and memory impairments, participants described profound emotional struggles, with some reporting intense feelings of depression and suicidal thoughts, which they linked directly to their experiences of LC.

> *"A few weeks after being infected I woke up feeling suicidal, planning the details of how to dispose of my body rather than depressed / discouraged…. It was a shock, and I was glad I spoke to someone knowledgeable instead of acting on it*" (pwLC9).

This statement highlights the stark reality that for some individuals, it is difficult to manage the effects of LC on mental and emotional wellbeing. The participants recognition of these thoughts as a common symptom of LC highlights the complexity of mental health challenges associated with the illness. Other participants echoed similar feelings of change and emotional strain. Participants described how their personalities had altered since having LC:

> "*I feel that Covid-19 has impacted by mental state and my personality. I have changed in how I respond to stimulus"* (pwLC48) and some found themselves struggling to cope independently: "*I had mental health issues that required seeking professional support"* (pwLC12).

This theme describes the significant difficulties in managing LC due to the unpredictable nature of the symptoms. Participants described experiencing a wide range of debilitating symptoms and the fluctuating and inconsistent nature of these symptoms presents challenges, making it difficult to plan activities or maintain a sense of stability. Strategies to support symptom management were reported as necessary by many participants, involving adapting their routines and pacing themselves to avoid triggering symptom flare-ups. These "crashes" highlight the struggle of balancing activity levels and minimising symptom worsening.

Theme Three: The perceived lack of support

A further theme that emerged was the perceived lack of support experienced by pwLC. Participants voiced their frustration about the lack of recognition and understanding of their illness by medical professionals. The lack of medical guidance, limited treatment options and the ongoing uncertainty surrounding the illness left many feeling isolated and unsupported as it has done for people living with ME (Fennell et al., 2021). A concern for some participants was the difficulty in obtaining a diagnosis for LC, while others described their experiences with healthcare professionals as dismissive, expressing that their symptoms were either downplayed or misunderstood. This lack of validation from medical practitioners led to strong feelings of frustration and helplessness *"Doctors have engaged in gaslighting and minimizing my experience*" (pwLC62). Others reported that their doctors did not recognise LC and without a formal diagnosis, they were unable to access appropriate treatments or resources that might have aided their recovery *"my GP doesn't recognise long covid, so I couldn't get a diagnosis and/or get helped*" (pwLC8). The uncertainty surrounding the nature of LC was another source of frustration as participants mentioned how this lack of clarity not only affected their physical health but also may have contributed to emotional distress "*the ambiguity about my health situation and recovery even from doctors causes frustration*" (pwLC24).

One participant mentioned how support for pwLC had changed over time:

> "*I was surprised at the lack of knowledge during the pandemic and lack of support for those who had Long Covid (albeit even undiagnosed). Support seems to be available post pandemic, which is a long time to manage symptoms independently*" (pwLC57).

However, by this time many participants had already been struggling with symptoms for months, often without medical support. Another difficulty pwLC shared was the invisible nature of LC which made it more challenging for them to receive the support and recognition. This may have contributed to a barrier to receiving appropriate support from those around them, as well as from medical professionals who may not have fully understood or acknowledged the impact of LC. One participant described

> "*I feel it's poorly understood and because most of it is invisible, it's not taken seriously by people in general. They're not aware of the impact it has on our lives and the pain we can experience*" (pwLC43).

One participant shared how the invisible nature of their symptoms made it difficult to communicate their needs: "*In addition, all of my symptoms are invisible which makes it very difficult explaining to others why I cannot undertake a task*" (pwLC61). The lack of visible symptoms often led to others doubting the validity of the participants experience, adding further emotional distress.

The lack of support for pwLC is not a novel finding. Previous research has highlighted that pwLC often face significant challenges in receiving appropriate care and recognition from healthcare systems and society (Gahan, 2022). Studies by Au et al (2022), Goldberg (2020), Mariani (2022), and Russell and colleagues (2022) all echo similar sentiments expressed by participants in this study, emphasising the widespread nature of medical dismissal, limited treatment options and inadequate healthcare services available. This lack of medical and societal recognition not only impacts wellbeing but also limits access to appropriate care, reinforcing the need for greater awareness and inclusion for pwLC.

Conclusion for Assessment One Analysis

The results from the thematic analysis of the survey responses from Assessment One reinforce the narrative that the impact of LC extends beyond the physical symptoms. The constructed themes highlighted the lived experiences of pwLC and their sense of loss, the multitude of the emotions they face, difficulty in managing their illness and a perceived lack of support. These findings emphasize the widespread disruption caused by LC which is not only affecting health but also independence, daily functioning and wellbeing.

Assessment Two: Thematic Analysis

During the coding phrase, numerous codes were generated which led to the construction of three themes. The themes that will be discussed are cognitive challenges, managing expectations and continued uncertainty and social isolation. During assessment two, participants had been living with LC for an average duration of 32.63 months (*SD* = 10.68).

Theme One: Cognitive Challenges

This theme captures how cognitive dysfunction was a significant concern among participants, affecting their ability to engage in daily tasks, work and social interactions. Many individuals described their struggles with memory loss, including forgetting simple words, experiencing significant lapses in recall and a lack of concentration which create barriers to everyday functioning. One participant, a medical professional described how cognitive challenges had affected their work

> *"I worry that I won't meet my publisher's latest deadline…. I forget too many medical words that I've known for 20+ years"* (pwLC23).

This quote highlights how even those with extensive expertise in their fields are experiencing cognitive challenges that directly impacted their professional abilities as well as personal struggles. These struggles are not just inconvenient, but they create career uncertainty and affect financial stability, particularly for individuals in roles that required high levels of cognitive function.

Participants reported that cognitive difficulties contributed to a reduction in their daily tasks, which was contributing factor to maintaining independence. Participant 14 expressed the impact of this "*Concentration / cognitive issues are the ones that really stop me functioning".* This captures how cognitive difficulties leave individuals unable to engage in their daily lives. Cognitive difficulties did not only affect work and daily activities, but they also had an impact on emotional well-being. Many participants described losing confidence in their ability to communicate effectively, leading them to avoid certain situations for fear of embarrassment. *"My memory loss and lack of concentration is affecting my confidence, and I find it extremely frustrating and at times embarrassing when my friends, colleagues, and family notice."* (pwLC2). Participants continued to experience severe limitations in cognitive function, particularly when it came to mental or emotional exertion. One individual described how their difficulties extended beyond typical definitions of fatigue: *"Inability to exercise or over-exert cognitively or emotionally. I feel this isn't really captured by the word fatigue."* (pwLC3). This statement demonstrates how cognitive exertion, much like physical exertion, can lead to crashes or worsening symptoms, as discussed above is common for individuals with post-exertional malaise (PEM). For many, cognitive tasks such as reading, problem-solving or even engaging in conversations can trigger a significant decline in cognitive function, leaving them mentally drained and unable to process information, which is similar to what was reported in the study one responses. This highlights that loss of ability and fatigue for some people was still ongoing at assessment two, which was up to seven months after the first assessment.

In contrast for some participants, there was some progress and improvement in cognitive function. One participant reflected:

> *"I believe that my cognitive function has improved quite well. Not sure how exactly to describe the difference, but I definitely feel mentally lighter, brighter, and cope better with mental tasks."* (pwLC8).

This statement highlights a gradual return of clarity and while the participant struggled to pinpoint specific improvements, they recognised a difference in their cognition compared to earlier in their illness.

Some participants described uncertainty about whether their cognitive difficulties, fatigue and memory issues were attributable to LC or part of the aging process which added further complexity, as it made it difficult to distinguish between symptoms that might have been expected with age and those that were a direct consequence of LC. There is some research to suggest that LC can accelerate the aging process (Guaraldi et al., 2022). This was pronounced in older participants and one participant stated

> *"I'm not entirely sure if some of my symptoms of fatigue are age-related"* (pwLC2), while another reflected, *"It could be that my problems with fatigue, memory, and concentration (not remembering my mission) are related to my age rather than lingering Covid symptoms"* (pwLC59), further adding to the uncertainty.

To summarise, this theme demonstrates how cognitive difficulties are impacting individuals in multiple ways. However, some participants reported signs of cognitive improvement, albeit gradual and difficult to quantify and others expressed uncertainty about whether their symptoms were solely due to LC or a natural consequence of aging. The period since initial infection highlights the enduring nature of the illness, particularly in relation to cognitive functioning and the impact of this.

Theme Two: Managing Expectation and Continued Uncertainty

This theme highlights the ongoing uncertainty of LC recovery and the difficulties individuals face in setting realistic expectations for their health. The need for careful pacing, the struggle against external pressures and the search for effective treatments all contributed to the complexity of managing with LC. While some participants found ways to navigate these challenges, others continued to struggle with the long-term implications. For many participants, managing expectations around recovery was a complex and evolving process which was shaped by the unpredictable nature of LC that was identified in theme one, conflicting information and external pressures to "get better." The absence of a clear treatment pathway led to uncertainty, with one participant expressing,

> *"There is so much conflicting information about how to recover from this illness. It's great to see the research finally being published about how dangerous Covid-19 and Long Covid is"* (pwLC37).

This highlights the difficulties individuals face in determining the best course of action for their recovery, often navigating with trial-and-error type approaches. The pressure to recover both from internal expectations and from societal pressures was another significant challenge. Some participants felt a growing burden as time passed *"I am struggling more now because I feel there's more of an expectation that I should've recovered"* (pwLC31). This statement underscores the misunderstanding surrounding LC, where assumptions about recovery timelines often do not align with the lived experience.

Some participants described the emotional impact of coping with LC, particularly when symptoms fluctuated as previously discussed. One participant said, *"recovery is quite long and it’s hard to balance mental health while struggling"* (pwLC24), demonstrating how the longevity of LC created additional pressure. Others expressed how symptom variability made it difficult to establish consistent routines *"every day is different, there doesn't seem to be a pattern, although, overdoing one day does lead to an increase of exhaustion for as long as several days"* (pwLC62). This unpredictability, which was also identified in assessment one, complicated efforts to regain a sense of normalcy as participants had to constantly readjust their expectations and energy levels. Pacing was frequently mentioned as crucial,

> *"Pacing is so, so important, but has been one of the hardest lessons to learn. Learning your own limits and not being pushed by others, even if they mean well, has to be a top priority"* (pwLC37).

Others echoed this sentiment, detailing how careful energy management was necessary

> *"As long as I work within my limitations and pace my activity throughout the day / week, then I manage to retain my baseline. Whenever I attempt to 'work' beyond those strict controls, either physically, cognitively, or emotionally, I suffer an exacerbation across several areas in my body"* (pwLC61).

These accounts demonstrate how living with LC requires a delicate balance of activity and rest, often involving self-monitoring to prevent symptoms worsening.

Despite these challenges, some participants reported gradual improvements over time. One individual shared,

> *"I've slowly seen improvements in all my symptoms since I last participated in the study… I am hoping to get a part-time job soon so I can become financially independent again."* (pwLC51).

Another described how medical and therapeutic interventions had played a role in their progress: *"Although I am not fully recovered, I have improved so much. Ketamine and Adderall are the medications that have helped the most. Also, physical therapy, occupational therapy, and speech therapy have helped tremendously. Some symptoms have gone away, perhaps only because of time."* (pwLC44). These experiences demonstrate that while recovery was slow and nonlinear, there was still potential for improvement albeit at different rates for each individual.

The process of managing expectations required pwLC to balance hope with realism. Some participants found ways to adjust to their new limitations, while maintaining as much of their previous life as possible. One participant explained,

> *"I am mostly living a full life now but occasionally have to reduce or scale back activities as I get tired. I can't do everything I want to, but I can do most of it."* (pwLC40).

Others highlighted trial and error with different treatments, pacing and lifestyle adjustments played a role in their recovery, as this participant shared,

> *"I have been trying various treatments / supplements (based on reputable Long Covid research) since January 2023. However, it is the maraviroc and statin combination that has led to significant improvements."* (pwLC73).

In sum, this theme demonstrates how pwLC are learning to manage and adapt to their illness. While the path to recovery was described as slow and uneven, there were also accounts of progress and adaptation. These narratives highlight the value of patient persistence and personal resilience. Ultimately, this theme illustrates that managing LC is not only a matter of addressing physical symptoms but also of navigating uncertainty, adjusting expectations and sustaining hope within the constraints of an evolving and often misunderstood illness, which are similar to the stages in the Fennell-four phase model, developed to help describe the process of living with chronic illnesses (Fennell, 2012).

Theme Three: Social Isolation and support

Social isolation emerged as a challenge for pwLC, exacerbating the already difficult experience of managing a chronic and unpredictable illness. Participants described their experiences with socialisation and there was a general feeling of increased disconnection from their social circles due to their limited capacity to engage in conversations, attend social events or maintain relationships in the way they once did.

> “*Worsened ability to participate in any social gathering without getting worse fatigue and pains. Hard to follow a conversation because I can forget what I wanna say, the words or what the person said”* (pwLC30). *“I used to be a pretty social person, but my ability to communicate effectively when I'm talking has gotten much worse. I've turned down chances to speak publicly, don't see friends as much”* (pwLC23).

Furthermore, as highlighted in the thematic analyses for Assessment One, the unpredictable and fluctuating nature of symptoms can cause disruptions to socialisation. “*I still need to consider my condition before agreeing to participate in something*” (pwLC40).

Online support has been validating for some people, while others have stated having support has enabled them to socially interact. *“Long Covid is incredibly isolating and a lonely place to be. People you expect least to not believe you, abandon or ghost you, and you learn who your true friends and support network are”.* These experiences point to the stigma and misunderstanding that continue to surround LC, exacerbating the isolation faced by those living with it. Despite these challenges, participants described finding alternative sources of connection and validation, particularly through online communities. The emergence of “spoonie” networks, online spaces for people living with chronic illness, provided both emotional support and a sense of solidarity. For some, these communities became lifelines *“the pros of living in an online world have helped build the "spoonie community" and the support this community has given has both been validating and supportive”* (pwLC37). Others noted the importance of having a strong support system that enabled them to remain socially engaged, even if their participation was limited *“I'm fortunate I have a* *good support to enable me to do some things I wouldn't otherwise do - i.e. theatre, music events"* (pwLC27).

This final theme underscores how social isolation, both physical and emotional, is a core part of the lived experience for pwLC This theme illustrates how important socialisation is for pwLC and how society can improve on greater understanding of LC to support recovery and psychological needs of pwLC (Missel et al., 2021).

Assessment Three: Thematic Analysis

In the thematic analysis of responses at Assessment Three, four themes were generated to highlight different aspects of participants' lived experiences. These themes are "the ongoing impact of Long Covid", "reinfection and the consequences", "barriers to medical support and personal resilience and adaption". During Assessment Three, participants had been living with LC symptoms on average for 46.5 months (*SD* = 10.24).

Theme One: The ongoing impact of LC

Despite living with LC for up to 44 months for some participants, the ongoing impact of LC was a central theme, that was evident in the previous thematic analyses. The experiences of many participants reflected a continued disruption not only to physical health but also to various other aspects of life. This theme emphasises the continuous challenges faced by individuals, the persistence of symptoms and the lack of a clear path to recovery. The emotional toll of LC is clear, with participants highlighting how LC affects their quality of life, social interactions, work and personal identity. The lack of medical understanding and effective treatment options contributed to a sense of isolation and helplessness, further intensifying feelings of loss and frustration.

> *"I just feel hopeless, it's hard to live with all these symptoms, and knowing that there is not [a] cure for it*" (pwLC2). Recovery is difficult, despite efforts "*I'm managing symptoms better than before but still very limited in what I can do in a day and very easily topple into not functioning at all and complete shutdown"* (pwLC41).

It was clear that fluctuating symptoms are still disrupting pwLC ability to work and socialise:

> *"My attempt at returning to work full time failed and I had to resign from a new position. I can go days without having extreme symptoms, only to have some of them come roaring back and full force, making it necessary to adjust plans. There is some predictability, if I overdo exercise or get visually / auditory overstimulated, I know I will need to slow down for a few days. But sometimes, it's not predictable, making it hard to work and maintain a social life*" (pwLC44).

The long-term changes and loss of abilities herein, that were difficult to manage in assessment one and the expectations that pwLC were facing in assessment two were also still apparent:

> *"It's life changing on a fundamental level - not just the physical symptoms but relationships, friendships, work, finance, abilities as a parent, social life etc"*

> (pwLC3). “*For my new role (job) learning new tasks has been difficult and my employer has made allowances and adjustments so I can fulfil this role*” (pwLC15).

It was clear that some participants were still struggling with frustration regarding medical professionals’ dismissal that was discussed in Assessment One, under the theme “perceived lack of support”:

> *“I feel like I'm getting nowhere with doctors, including neurologists. They either tell me that they don't know anything about it, or that no one's proven it exists…. they tell me there's nothing wrong”* (pwLC23).

A response provided by participant 35 conveys a sense of devastation, highlighting the impact LC has had and continues to have on their life and on their sense of self which was seen in the sense of loss theme in Assessment One:

> *“I am shocked that in the time since first having a severe covid infection, and subsequently getting it twice more, I now find myself completely unrecognisable, physically and cognitively, despite my best ongoing efforts to do what I can holistically to self-manage, since there is little help available medically now. I'm getting worse in severity of symptoms… my world has shrunk to one room - I had to move my bed downstairs a year ago as I could no longer get upstairs…My symptoms have forced me from an organised, super busy, very sociable and confident multitasker, managing a team at work, able to cook & host meals for a large number, organise parties, to a shell of a person, a hermit, hiding in my home, seeing no one, afraid to open the door “ (pwLC34).*

The expressions “completely unrecognisable, physically and cognitively” and “shell of a person” captures the extent of the changes they have undergone since their Covid-19 infection and links back to sense of identity also raised from Assessment One. The deep sense of loss expressed in this quote captures the overwhelming emotional, psychological and physical impact of LC. This statement also highlights the often-invisible struggle faced by many with LC as they navigate not just physical symptoms but the complex emotional landscape of chronic illness and its effect on their identity and future.

Conversely, one participant noted improvements although they reported still experiencing some symptoms:

> “*I'm much better than I was. Only experience a feeling of being more tired than normal, but not as extreme as fatigue. I would call it tiredness rather than fatigue. My sore throat symptoms are rare, but I can still lose my voice if dealing with a stressful situation”* (pwLC40).

The fact that stress can trigger symptoms, like voice loss, speaks to the psychological burden of living with LC. Stress is often a trigger for symptom flare-ups in many chronic illnesses (de Dios-Duarte et al., 2022) and it adds an additional layer of difficulty to managing the illness. The comment by one participant, “*My brain stuff continues to decline, it never has gone back to pre-Covid. I stabilise for a month or so and then decline some more*” (pwLC54), encapsulates the ongoing and progressive nature of cognitive difficulties experienced by some pwLC. Rather than following a linear recovery trajectory, cognitive functioning in this case appears to fluctuate, with periods of relative stability followed by further deterioration.

To summarise this theme highlights the persistent and continued impact of LC, after an average of 46 months of living with LC. Participants described a continued struggle with fluctuating symptoms, limited recovery and profound changes to daily functioning, identity and emotional wellbeing. The survey responses reflect not only physical and cognitive deterioration but also significant continued disruptions to work, social relationships and overall quality of life. Many participants reported experiencing frustration and isolation, especially due to a lack of effective treatments and dismissal by others. While some noted gradual improvements, the overall picture presents the long lasting sequalae of LC.

Theme Two: Reinfection and the consequences

This theme highlights a critical aspect of LC, the impact of multiple infections on an individual's recovery and symptom burden. These experiences underline how reinfections not only prolong recovery but also potentially worsen or introduce new symptoms.

> "*One of the hardest things about having Long Covid is trying to avoid reinfection in a world which does not seem to see this as at all important and normalises repeat illness" (pwLC3)*.

This quote highlights the frustration pwLC feel about societal attitudes towards reinfection. Participants feel that as the world moves on from the pandemic, there seems to be less emphasis on protecting those at risk from reinfection. Individuals with LC often face the challenge of living in an environment that underestimates or dismisses the severity of repeated infections, especially when these reinfections can exacerbate their chronic symptoms. This perception can create a sense of isolation and misunderstanding for those who are attempting to protect their health, only to find that reinfection is often viewed as a normal, almost inevitable part of the pandemic's aftermath, due to a lack of awareness or acknowledgement that reinfection may affect pwLC much worse than those without.

Reinfections may not necessarily follow the same pattern as the initial infection and pwLC may experience new or different symptoms when reinfected:

> "*It might be worth noting that more recent bouts of covid have left different residual symptoms - e.g. earache and rashes, but other symptoms have not increase" (pwLC21). "I have had covid three times. I last was 2024. Since then, my memory has had a significant hit" (pwLC26).*

This comment reveals a concerning possibility that reinfection may contribute to cognitive decline. This further reinforces the progressive nature of LC for certain individuals, where cognitive function continues to deteriorate despite initial recovery. The fear of reinfection is not just about getting ill again but about the long-term consequences that each subsequent infection can have on their overall health. This fear can create a sense of anxiety or helplessness: "*If I get another infection then makes the long covid worse" (pwLC27).* One participant shared an account of how reinfection can also make physical health worse:

> “*My legs are greatly affected. The first time I had covid I had to relearn walking they were so weak and every time I get a repeat infection it seems to eat away at my leg muscles, and they are visibly much thinner after each infection. It takes a long while to build them up again. I cannot walk far without my mobility aids” (pwLC67).*

This highlights the toll of LC, in relation to physical health and mobility, e.g. relearning to walk after each infection and the progressive muscle wasting that occurs with reinfection. This account provides a picture of the chronic and debilitating nature of the illness.

This theme felt important to acknowledge, as the significant and often overlooked impact of repeated Covid-19 infections on pwLC. Participants reported that reinfections not only delay recovery, but also can introduce new or worsening symptoms, which further complicate their health and functioning. The uncertainty and unpredictability of how each reinfection will affect their body may to anxiety.

Theme Three: Barriers to medical support

This theme discusses the significant challenges that pwLC continue to face in accessing adequate medical care. These barriers include inadequate healthcare access, financial limitations, stigma and disbelief from medical professionals. Furthermore, the privilege of being able to privately fund treatments has been acknowledged by participants and how that has played a role in the accessibility of treatments. While some individuals manage to find solutions through private care and experimental treatments, many others struggle due to the lack of resources and institutional support.

Some participants highlighted the inaccessibility of adequate care within the public healthcare system, where services such as Long Covid clinics were described as overwhelmed or unable to provide tailored support. For some, even when referred to specialist clinics, their illness was too severe to participate in therapy. As one participant shared:

> "*I was discharged from the LC clinic 6 months ago, unable to even start working with Physio at that time as I was too ill to engage*" (pwLC34).

This account speaks to a critical gap in care: individuals most in need of intervention may be too unwell to begin it yet face discharge due to this very incapacity. This lack of intervention may contribute to patients feeling disconnected from the healthcare system, as discussed in previous themes, as well as not receiving the support they require.

Financial barriers emerged as a major obstacle. While some participants were able to access private healthcare, this was often described as a privilege not available to all. Many reported significant costs for diagnostic testing, medications and alternative therapies not offered by the NHS. As one participant said

> "*The improvements I have made have only been as a result of experimental medications which private doctors have been willing to prescribe. It is also*

> *very expensive as most of the treatments that seem to help at all aren't available on the NHS"* (pwLC3).

Similarly, another participant recounted that although privately funded testing had been beneficial, it remained an incomplete and costly solution

> *"I had private in-depth blood tests for levels, hormone & gut health investigations have helped significantly, but are not a 'one stop shop' cure by any means*" (pwLC 34).

These statements reflect a common issue where pwLC are left to navigate expensive private care to find relief, while NHS services may not offer the same treatments. This creates a situation where only those with the financial resources to pay for private treatments have the ability to seek care that may provide some level of improvement, while others who cannot afford it are left without adequate options.

In summary, this theme underscores a critical need for more affordable, responsive and informed care for pwLC. Addressing these barriers will require changes including improved training for healthcare providers and increased funding for expanded access to treatments through public services. Without such interventions, many individuals will continue to not have adequate support in their recovery and treatment options.

Theme Four: Personal Resilience and Adaptation

This theme captures the strength, perseverance and adaptability that pwLC have developed in response to the ongoing challenges of living with a chronic and often unpredictable illness. While previous themes explored the difficulties associated with symptom burden, social isolation and barriers to medical care, this theme focuses to how individuals navigate and cope with these difficulties in their everyday lives at later stages of their experience of living with LC. It reflects a growing body of strategies and mental shifts that illustrate the resourcefulness and personal growth many participants experience on their LC journey. This theme covers both the gradual improvements people are experiencing and the ongoing limitations they face, capturing their ability to balance optimism with reality. One participant said *“It is quite tiring and long recovery, but it made me stronger, I don't give up trying to find new ways to feel better”* (pwLC24) which speaks to the personal growth that some individuals experience throughout their LC journey. Despite the fatigue, frustration and long recovery times, there is a sense of strength and determination to keep going. Furthermore, the effort to find new ways to feel better reflects resilience, a refusal to give up even when progress feels slow or uncertain.

Some participants are managing better and have made progress to being able to access the community more at this later stage than was previously possible, demonstrating that while improvements are gradual, they have been possible: “*I am managing my condition much better than before, and I am no longer housebound” (pwLC37).* Furthermore, this demonstrates the management of their illness to enable reengagement in everyday activities. Another example of their managing and adapting was expressed as follows: “I have learned to adapt to fatigue, the cognitive issues cause frustration and embarrassment” (pwLC46). While these cognitive issues remain a source of frustration and embarrassment for some, there is an acknowledgment of the need to adapt and adjust strategies for functioning.

This final theme demonstrates the adaptability of pwLC. While many continue to experience significant limitations, pwLC in this sample show persistence and hope as they discover new ways of living. These personal stories illustrate that recovery is not always linear or complete, but these stories of resilience, adaptation and an evolving sense of what it means to live with LC are profound and powerful and may help those who are earlier on in their recovery journeys too.

Conclusion for Assessment Three analysis

Together the themes within this analysis demonstrate the long-lasting and multifaceted difficulties pwLC are facing with regards to their symptoms, fears and healthcare access. There has been resilience shown by pwLC as they demonstrate ways in which they are overcoming these. These findings highlight not only the persistent physical and cognitive challenges, but also the emotional and social struggles that shape the everyday realities of pwLC.

Synthesised results of all themes

Together across the three assessments, the themes consistently demonstrate how LC is affecting daily functioning, cognition and much more. When synthesising the assessments together a longitudinal overview emerges that for some people. LC is life changing with profound loss and disruption. Many participants described grief, altered lives and disconnection from their previous selves. Similarly, individuals with ME often experience grief from functional losses, as well as trauma related to how others including healthcare professionals respond to their chronic illness (Fennell et al., 2021).

The themes also provide insight into potential gaps in medical support and societal recognition of LC. The reports of lack of support, both from medical professionals and society, suggest that raising awareness is still vitally needed and critical for long-term support for this population. The multitude of emotions and the loss of independence felt by the participants demonstrate the need for multidisciplinary support in which psychological support, alongside rehabilitation would be beneficial. At the time of data collection for Assessment One, between March 2023 and July 2023, shortly after the third anniversary of the United Kingdom first lockdown (Glover, 2023), support for pwLC remained limited. Although it had been between 18 and 24 months since the WHO provided a formal definition of LC, meaningful and accessible treatment options may have still been limited. Only four months prior, the NHS announced the launch of specialist LC clinics across the UK, supported by a £10 million funding package (NHS, 2020). However, the demand for these services quickly outpaced availability, with many clinics reporting waiting lists exceeding 12 months (Mahase, 2024).

At the same time, public health structure was being significantly scaled back as Covid-19 testing was reduced (Roberts, 2023), NHS Test and Trace services were discontinued (Ferreira et al., 2023), and the WHO declared that Covid-19 was no longer a global health emergency (‘Covid Global Health Emergency Is over, WHO Says’, 2023). This broader shift in public messaging may have contributed to a growing sense among people with LC that the world was moving on, leaving them behind to cope with persistent, life-altering symptoms without adequate or readily available support, which again has been expressed by individuals with myalgic encephalomyelitis (de Carvalho Leite et al., 2011)

Across assessments the fluctuating cognitive and physical symptoms created a sense of uncertainty and distress to pwLC. Symptoms including memory difficulties and debilitating fatigue contributed towards limitations in daily life and impacted pwLC ability to work. The emotional consequence of LC were present throughout all the assessments and feelings of frustration, embarrassment and reduced confidence was reported. The management of fluctuating and debilitating symptoms meant that pwLC continuously needed to reassess their capabilities and expectations to prevent “crashes” These crashes, similar to the post-exertional malaise (PEM) experienced by individuals with ME/CFS (Stussman et al., 2020), can be debilitating and exacerbate the impact of LC.. The cognitive challenges significantly impact daily functioning. For some, this led to frustration, embarrassment and a loss of self-confidence. Some participants expressed uncertainty about LC, raising concerns about their long-term cognitive health and the lack of clear guidance.

The limited societal recognition of LC and social isolation led to some participants feeling isolated, invisible and disbelieved. This included with medical professionals which has been previously reported (Gahan, 2023; Lowenstein. 2022). Many felt that others struggled to understand or validate the extent of their cognitive and physical symptoms, leading to alienation. This is similar of reports of patients with ME who fear isolation, being disbelieved and embarrassed by their symptoms (Fennell et al., 2021). The need to limit social engagements to preserve energy or avoid reinfection contributed further to their isolation. For some individuals, having support networks appeared to help with the impact of LC on their daily lives which may suggest that with support, the reality of living with LC related difficulties may be more manageable. This has been suggested by previous research (Reblin & Uchino, 2008) which highlights the role of social support to promote wellbeing and reduce feelings of isolation.

Access to appropriate and effective medical support remained a major challenge for pwLC. PwLC described limited availability of specialised services as well as lack of continuity in care. Others spoke of the disbelief or dismissal they encountered from medical professionals, which some participants referred to as medical gaslighting. Financial barriers featured in the lived experiences, with several turning to private healthcare and experimental treatments in the absence of sufficient support from the NHS, often at considerable expense. The lived experiences shared demonstrate the inequalities in access to care, as only those with financial means can explore potentially beneficial treatments, leaving others potentially without viable options.

Resilience and adaptation were strategies some participants used reflecting a process of self-management. Participants described how pacing and careful management of their capacities helped to support their fluctuating needs. Reinfection reemerged as a significant concern among pwLC, with many describing a worsening or reemergence of symptoms following subsequent Covid-19 infections, These highlight the effect that reinfections can have on pwLC, including the introduction of new symptoms and exacerbation of existing ones. PwLC expressed fear and frustration around reinfection.

Across the assessments, the themes demonstrate the non-linear recovery pathway of LC. Consistent with the presentation of LC, Smith and colleagues (2019) describe how post-stroke adjustment is similarly non-linear. They discussed how stroke survivors may move from positive coping into distress when they have triggers such as physical setbacks. The authors present a model whereby positive and negative trajectories interconnect with ongoing adjustments and triggers (Smith et al., 2019).

The themes within these analyses interacted in a similar manner and demonstrated that multiple factors associated with LC shape the lived experience. Based on these interconnections, a conceptual model was created to reflect the multifaceted nature of LC (Figure 35).

Figure 35. Living with Long Covid: A conceptual model

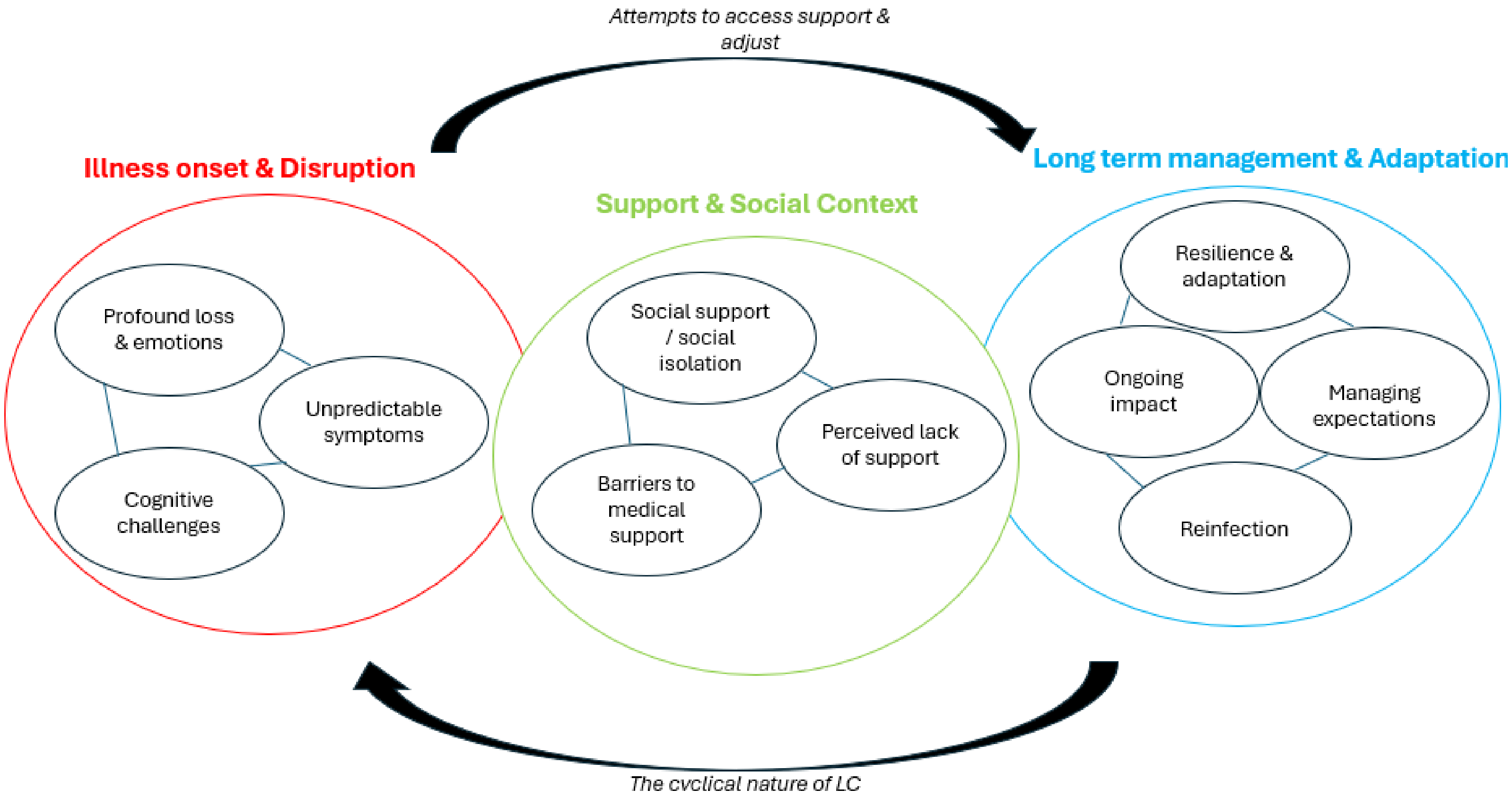


Figure 35 displays the complex, interconnected nature of LC. Each cycle represents a dimension of the experience; however, the cycles are connected.

The Illness onset and disruption cycle captures the immediate emotional and physical impact of LC. The profound sense of loss and the multitude of emotions are closely linked to the unpredictable symptoms and cognitive challenges. This cycle demonstrates how these unpredictable symptoms and cognitive challenges interact with emotional distress and sense of loss.

The support and social cycles highlights the attempts to access support. Social isolation emerged as a consequence of being unwell and also as a protective factor to avoid reinfection. This isolation reinforces perceptions of lacking adequate support, which is further compounded by barriers to medical support. These barriers fed back into both isolation and the perception of being unsupported, creating a cycle of disconnection. However, social support appeared to help break this cycle for some participants.

The long-term management and adaptation cycle encompasses the ongoing adjustment process involving managing expectations, reinfection and building resilience and adaption. Rather than presenting recovery, this cycle captures the reality that many pwLC continue to experience persistent impact across multiple areas of their lives. The ongoing impact of LC, including continued reduced functional limitations and effect to employment, requires constant management of expectations, both on personal and societal levels. The need to manage expectations feeds into adaptive processes to accommodate fluctuating health. Some pwLC develop resilience and adaptive strategies which include pacing and increased use of compensatory strategies. These strategies help some people to regain a sense of stability in the present of ongoing symptoms. However, adaptation is not linear as the model highlights the role of reinfection can trigger a return to an earlier cycle of uncertainty and needing more support. This reinforces the cyclical nature of LC and how continuous adjustment is required rather than a single linear recovery trajectory. Overall, this cycle reflects the ongoing process of living with LC rather than recovery from LC.

In sum, the model demonstrates how the cycles interconnect to shape lived experience of LC. These cycles do not exist independently. The multitude of emotions in the illness onset cycle interconnects with social isolation in the second cycle. Barrier to medical support worsens the ongoing impact of LC illustrated in the long-term management cycle. This model provides evidence that continuous management, support and interventions are required. This model may inform clinicians’ understanding when supporting pwLC, to know what to look for, assess and consider for pwLC depending on where they are on their LC journey. For example, addressing acute disruption would require different care to supporting long term adaptation. This model shows that LC is not a collection of separate difficulties but an integrated system of difficulties that require interventions at multiple points to improve patient outcomes.

Discussion

These results from these thematic analyses align with the quantitative results in the previous chapter. Managing the unpredictable and fluctuating symptoms identified in Assessment One, alongside the ongoing struggle to manage both personal and external expectations observed in Assessment Two and the added consequences of managing reinfection noted in Assessment Three, collectively they illustrate the persistent and evolving challenges faced by participants. This aligns with previous themes that have emerged, ‘a serious, uncertain and confusing illness’ (Ladds et al., 2020), ‘the life changing impact of the condition’ (Ireson et al., 2022) and led to participants providing rich descriptions of cognitive symptoms (Callan et al., 2022).

The management of LC has been explored in previous qualitative research highlighting the various strategies individuals attempt to navigate their symptoms and maximise their daily functioning (Macpherson et al., 2022). In other LC research, participants have described the “hard and heavy work” of enduring and managing ongoing symptoms (Kingstone et al., 2020), which reflects the sustained effort required to cope with a condition that is both unpredictable and poorly understood. These findings resonate when participants described the physical, cognitive and emotional toll of continually adapting to their fluctuating health.

Supporting individuals with chronic illness through self-management has been a key focus in healthcare literature for over 50 years (Novak et al., 2013). The concept was introduced by Thomas Creer (Creer, 2000) in his work with chronically ill children. Since then, research has focused on understanding the skills and competencies, necessary for effective self-management. This body of work has informed the development of structured approaches and interventions aimed at empowering individuals to take an active role in managing their chronic conditions (Novak et al., 2013) and may be beneficial to some pwLC.

Participants expressed depression and anxiety, related to the impact of LC. These responses again are not uncommon in chronic illnesses and have been observed in previous epidemics such as MERS (Park et al., 2020). Research has highlighted similar struggles with depression and anxiety in stroke survivors (White et al., 2014), individuals living with diabetes (Manderson & Kokanovic, 2009) and patients with ME / CFS and fibromyalgia (Asbring, 2001). Previous qualitative LC literature has also reported the presence and risk of depression and anxiety in pwLC (Burton et al., 2022) and other research has suggested that the Covid-19 pandemic was a source of mental health trauma (Bridgland et al., 2021). The uncertainty surrounding the possibility of reinfection was a recurring source of anxiety among participants and significantly impacted their psychological wellbeing. This fear appeared to not only stemmed from the physical health concerns, but also from the potential for further cognitive decline or regression in recovery. For many pwLC who already live with fluctuating symptoms and limited functional capacity, the idea of worsening due to reinfection created a sense of fear and anxiety. In addition, these emotional challenges may arise from the loss of identity and functional ability, which were strongly echoed by pwLC.

However, there was indication of a shift towards acceptance, resilience and adaptation in some participants at Assessment Three. Adaptation to chronic illness is recognised as a vital process and has been explored in a range of conditions, including with patients of chronic obstructive pulmonary disease (COPD) (Uchmanowicz et al., 2016), those with diabetes (Bertolin et al., 2015), and people with ME/CFS (Catchpole & Garip, 2019). Research highlights the influence of illness perceptions on key outcomes in chronic illness, such as self-management behaviours and overall quality of life (Petrie et al., 2007). Furthermore, levels of acceptance and adaptation have been found to correlate with psychological wellbeing, particularly with respect to depression and emotional adjustment (Uchmanowicz et al., 2016).

The processes of adaptation and learning to rebalance life with LC, have been explored in lived experience qualitative studies, and emphasise how individuals gradually come to terms with their condition through strategies such as pacing and adjusting expectations (Humphreys et al., 2021). These findings align with the current study, where some participants moved through phases of loss and disruption, toward varying degrees of acceptance and adaptation over time by the third and final analysis.

Despite retaining some independence, participants continued to be limited in their capacity to engage in everyday life activities up to 60 months post infection. This was reflected in their survey responses whereby participants described activities they were no longer able to participate in, including elements of personal care and work. This led to a sense of grief and loss within participants. The profound sense of loss and grief was evident across all the thematic analyses, reflecting the emotional and functional disruptions experienced by participants, which has been documented in previous qualitative research in pwLC (Burton et al., 2022). Qualitative research with individuals living with chronic physical illnesses has also identified themes of loss and sorrow (Ahlström, 2007), including chronic conditions such as HIV (Lichtenstein et al., 2002) and Parkinson's disease (Roos, 2014). These studies concluded that participants experiences were consistent with the phenomenon of chronic sorrow, highlighting the persistent emotional burden that can accompany long-term illness. This phenomenon refers to the ongoing, grief experienced in response to persistent loss, particularly in the context of long-term health conditions and may have been present in some of the participants who contributed to this study. Participants described a mourning for their former selves and their previous capabilities. This grief was not at a single assessment point, but rather a continuous emotional response throughout, which appeared to be hindering daily cognition and causing limitations in functioning.

The themes drawn from the qualitative data collected in Assessments One, Two and Three offer important insights into the lived experiences of pwLC. These themes illustrate that LC is not just a persistent set of physical and cognitive symptoms, but it is an illness that profoundly affects personal identity and self-worth. It was apparent that the loss of the participants pre-Covid functionality and independence was perceived as grief for a previous self. This, alongside the non-linear and unpredictable nature of symptoms, makes recovery difficult to track and often leads to frustration and feelings of hopelessness. A recurring theme across the data was the perception of insufficient medical and societal recognition, which contributed to feelings of invalidation and marginalisation. Participants reported barriers to accessing care, either due to the severity of their symptoms, financial constraints or from disbelief of professionals which has been reported previously in pwLC (Au et al., 2022; Goldberg, 2020; Mariani, 2022; Russell et al., 2022). The themes identified in the separate assessments did not emerge in isolation at each time point, rather they appeared to evolve and overlap throughout the study.

The perceived lack of support identified in Assessment One, was echoed in Assessment Two with social isolation and in Assessment Three with participants continuing to report barriers to both medical and social support. This suggests that insufficient provisions remained a persistent issue over the 24-month period, hindering participants ability to obtain appropriate, accessible treatment and support. Unfortunately, such findings are not uncommon in the qualitative literature on LC, with several studies documenting similar challenges faced by individuals in navigating healthcare systems (Burton et al., 2022; Callan et al., 2022, Day, 2022; Kingstone et al., 2020, Ladds et al., 2020, Taylor et al., 2021, Samper-Pardo et al., 2023, Shelley et al., 2021). Some participants in the present study expressed they were able to access private healthcare to support their symptoms and aid recovery. While this provides access to specialised treatments, it also highlights a concern for those who are not financially able to access private treatment options. This concern was also raised by pwLC in research by Burton and colleagues (2022) and highlights an issue within equality / inequities with those from marginalised communities, including individuals from lower socioeconomic backgrounds, ethnic minorities and disabled individuals that may be affected by LC and unable to access adequate support. When care is based on financial means, marginalised groups are more likely to face barriers that may delay recovery. As discussed earlier, many pwLC often are unemployed, thus receiving a reduced income and financial insecurity. This may limit their ability to seek regular private treatment. Similar barriers are also often the case for people with ME / CFS (Fennell et al., 2021).

Marginalised groups that are already at risk of poor mental health, have been reportedly impacted by LC (Camara et al., 2023) and marginalised communities have exhibited a disproportionate burden of the direct and indirect impacts of the Covid-19 pandemic (Green et al., 2021; Wachtler et al., 2020). Research has shown that people with chronic illnesses from marginalised backgrounds tend to experience worse prognoses and face more barriers to care (Marmot, 2006), thus adequate, equal access to care is vital to the LC community. While it is acknowledged that the NHS is under significant financial pressures (NHS, 2024), adequate and sustained funding remains essential to ensure the provision of pharmacological support, the continued operation of multidisciplinary LC clinics and raising awareness of LC. Access to appropriate treatment options is crucial for pwLC. In the United Kingdom, there were initially 120 specialist LC clinics established nationwide, however as of May 2025, only 46 clinics have confirmed they will remain operational (Long Covid Support, 2025). Furthermore, the rehabilitation support that was created and issued by the World Health Organisation (2021) has since been suspended. This reduction in services raises concerns about the long-term future of healthcare to meet the needs of pwLC.

Social support appears to play a critical role in the lives of pwLC, helping to mitigate the impacts of the illness. PwLC in this study highlighted the importance of supportive relationships, whether from family or online communities, in helping them to validate their experiences. For some, social networks provided emotional reassurance and practical assistance, however, others described social isolation or a perceived lack of understanding from those around them. These findings echo existing research suggesting difficulties with social support for pwLC (Burton et al., 2022; Callan et al., 2022; Samper-Pardo et al., 2023; Schiavi et al., 2022).

The qualitative data provides evidence that the ability to work can be compromised in pwLC. Participants described the loss of employment and reduced capacity to work, which aligns with the cognitive impairments observed. These impairments may make work increasingly difficult to navigate, not only with the cognitive impairments but the other factors involved in LC, such as fatigue and the unpredictability of symptoms. Given that approximately six in every 100 people who catch Covid-19 will go on to develop LC (WHO, 2025), this considerable impact to both affected individuals and the economy is not only a current problem but could potentially affect employees and employers for some time to come. Although the prevalence of Covid-19 is lower than earlier in the pandemic and the vaccines have mitigated some of the risks (WHO, 2025), Covid-19 is still circulating. Thus, the risk of LC development remains ever present and its impact on employment remains an ongoing concern.

The valuable accounts provided in the open-ended survey responses highlighted the need to further explore specific memory problems from a lived experience perspective. This led to the development of a semi-structured interview study to capture the memory difficulties and how these affects daily functioning (Chapter Four).

Chapter Four: Semi Structured Interviews

Introduction

As discussed within this thesis, the term ‘brain fog’ encompasses the long lasting sequalae of Covid-19 including attention, concentration, processing speed and memory (Merad et al., 2022). There have been suggestions that pwLC can demonstrate frontal dysexecutive syndrome with high levels of fatigue, problems with memory and attention (Voruz, Allali, et al., 2022). However, despite growing quantitative literature into cognitive deficits for pwLC, including memory and learning and how problems can persist over time (Ferrucci et al., 2021), the lived experience of these symptoms, particularly memory difficulties remain largely underrepresented in qualitative literature. The use of qualitative research has been encouraged to aid understanding of behaviours, social interactions and strategies that can be beneficial to pwLC (Teti et al.,2020*).* Qualitative data adds lived experience perspective to a study, as evidenced in the accounts provided by participants in the open-ended survey responses in the previous chapter. These lived experiences capture the impact of living with a condition, alongside the cognitive outcomes which were presented in Chapter Two. The mixed method nature of this thesis provides evidence of the impact of qualitative data, to help bridge the gap between performance and lived experiences. Qualitative research has been conducted to explore the lived experiences of pwLC, in relation to cognitive symptoms (Ladds et al., 2020; Samper-Pardo et al., 2023; Schiavi et al., 2022; Schmachtenberg et al., 2023). Qualitative studies have discovered themes around symptoms of LC (Burton et al., 2022; Humphreys et al., 2021; Kingstone et al., 2020; Lerer et al., 2022; Macpherson et al., 2022), including cognitive symptoms (memory and brain fog) (Callan et al., 2022; Ireson et al., 2022).

One study used a qualitative, interpretivist approach using focus groups and thematic analysis, underpinned by a contextualist epistemological standpoint to explore the lived experiences of those pwLC suffering with 'brain fog' (Callan et al., 2022).Participants were invited to describe their neurocognitive symptoms in focus groups and six emergent themes were present: naming the phenomenon brain fog, neurocognitive symptoms and their history, neurocognitive symptoms in the context of other LC symptoms, psychosocial impact, self-management and navigating healthcare (Callan et al., 2022). Impairments in executive function, memory and language were subjectively reported within the sample, which echoed findings reported in quantitative research (Guo et al., 2022; Hampshire et al., 2024; Jennings et al., 2022). Although this is a large qualitative study exploring neurocognitive symptoms of LC, the study did contain some limitations including the United Kingdom only based sample, and had a lack of demographic subgroups which may impact the generalisability of the findings. Similar limitations were discussed in the meta-analysis of qualitative research (Hossain et al., 2023). The meta-analysis reported that predominately qualitative LC studies have used descriptive designs including semi-structured interviews and / or focus groups which have been analysed through thematic analysis. These studies focused on subjective experiences of pwLC. The meta-analysis demonstrated a lack of mixed methods research as only a few studies had used qualitative data with cognitive measures.

Mixed methods research can support improved understanding of a particular condition (Tashakkori & Teddlie, 2003c) and is often used in health research to ensure a well-rounded picture is captured (Östlund et al., 2011). The use of both qualitative and quantitative methods within this thesis, will improve insight into the sequalae of Covid-19. The consequences of the long-lasting nature of LC may be underestimated (Rizzo & Paolisso, 2021) and there are concerns about how healthcare systems will meet the demands raised by the needs in this population in the future (Badenoch et al., 2022), thus further understanding is vital. This chapter provides an overview of the aims, methods, results and discussion, conducted on the transcripts of semi-structured interviews. As with the previous studies in this thesis, this focuses on individuals of working age, who may be juggling professional responsibilities alongside complex health challenges.

The results consist of three sections. Firstly, a presentation of the findings of an exploration into whether pwLC subjectively identify specific challenges related to established cognitive and memory models, such as those outlined in Atkinson and Shiffrin's multi-store model of memory (MSM; Atkinson & Shiffrin, 1968). For example, do pwLC identify issues with specific aspects such as rehearsal or retrieval? Furthermore, we investigated whether different types of memory are more vulnerable than others in this population, for example, whether short- or long-term memory are better preserved from a lived experience perspective. Secondly, the results present findings of two of the interview questions that were analysed quantitively to explore autobiographical memory. These questions focused on personal autobiographical memory (AM) and visualising a future event and were analysed using the Adapted Autobiographical Interview (Levine et al., 2002) to provide quantitative data. The analyses were exploratory, however, they aimed to explore, differences between episodic and semantic elements in memory and to explore any differences between past autobiographical memory details and future, imagined event details. Thirdly, the results present themes constructed during thematic analysis.

Methodology

Participants

Although semi-structured interviews are the most frequent source of data collection in health-related research (DeJonckheere & Vaughn, 2019), guidance for sample size remains unclear. It is recommended that the sample sizes are large enough to allow for rich data collection but small enough to allow a thorough analysis (Sandelowski, 1995). Research by Guest and colleagues (2006) concluded that theme saturation occurred within 12 interviews. In previous qualitative research with pwLC, the sample sizes have ranged from eight participants (Lerer et al., 2022) to 56 participants (Ladds et al., 2020). This study intended to recruit 20 participants taking into consideration guidance from (Sandelowski, 1995). Participants were only recruited if they met the criteria shown in Table 24.

Table 24. Inclusion/exclusion criteria for semi-structured interviews

Inclusion criteria	**Exclusion Criteria**
People with LC who have a confirmed formal diagnosis with accompanying record.	People without a formal diagnosis.
Concerns with acute memory difficulties such as implicit procedural memory, spatial memory, explicit episodic / semantic memory in their everyday lives.	Those with more generalised 'brain fog' rather than specific memory difficulties.
Aged between 18 to 65 years.	Those aged under 18 years or over 65 years.
Tolerance to participate in a Zoom interview for up to 60 minutes (participants were informed this could be split into two sessions of 30 minutes	Those who do not have internet access to join a Zoom session (due to the need for recording and transcribing the interviews) to reduce cognitive burden)

A final sample of 26 participants was recruited and their data included for thematic analysis. The participants ranged from 28 to 60 years of age (*M* = 45.57, *SD* = 9.43). The participants had between 10 and 20 years of education (*M* = 16.78, *SD* = 3.01). Twenty-three participants (88%) were female. The participants were from three countries; *N*= 24 (92.31%) were from the United Kingdom, *N* = 1 (3.85%) was from Norway and *N* = 1 (3.85%) was from the United States of America. All participants who completed the study were entered into a prize draw to win a £50 Amazon voucher. The prize draw was done using an online random generator tool. The winning participant was then contacted and received the voucher via email.

Ethics

Ethical approval was granted from the University of Essex Department of Psychology, ethics number ETH2425-0333. As in the previous studies, all participants for each study gave informed consented that was captured using the Qualtrics platform. To protect confidentiality, participant numbers were used and all data was securely stored on a password protected computer only accessible by the research team (i.e. researcher and supervisors). Participants were informed during the consent process that they could withdraw from any of the studies at any time, without giving any reason and that any data collected up to that point would be securely destroyed upon request.

Recruitment

A recruitment poster which provided information about the study and invited eligible individuals to take part, was distributed to individuals who had taken part in earlier phases of LC research within this thesis, and it was also circulated via social media LC support groups.

Materials

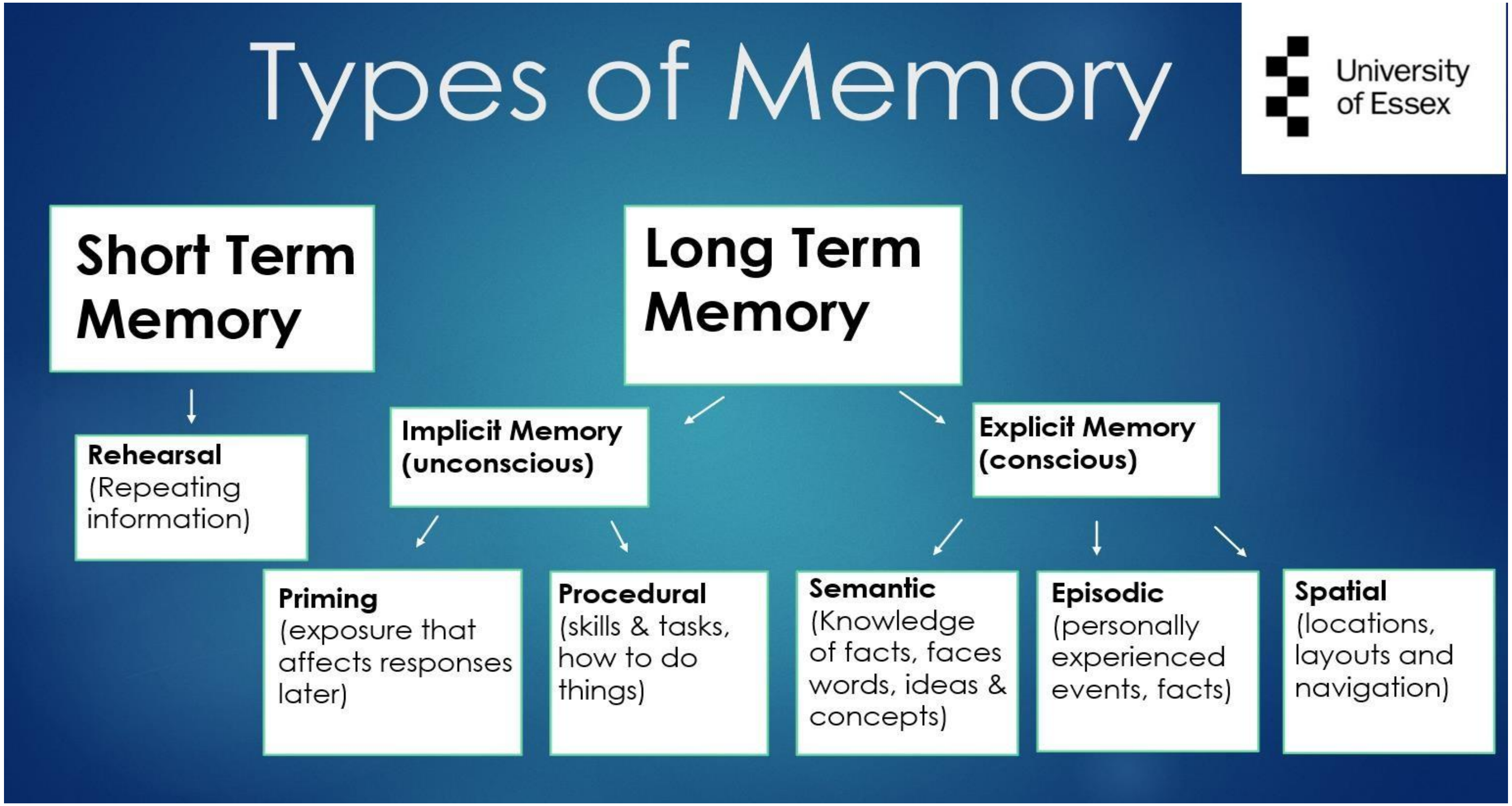
Questionnaire

All participants were sent a questionnaire via Qualtrics that captured demographic information, and included questions related to previous Covid-19 viral infections and their LC symptoms, alongside daily limitations. This was the same survey that was used in the previous studies. The questionnaire included the Chalder Fatigue Scale (Cella & Chalder, 2010) and the Quality of Life scale (Flanagan, 1978) that were used in the previous studies.

Prompt slide

A PowerPoint slide was created to provide participants with a visual prompt outlining the main types of memory in lay terms (Figure 36). This slide remained visible throughout the interview. This was primarily used to reduce cognitive load by alleviating the need for participants to recall and retain detailed information about memory categories during the interview.

Figure 36. Visual information for participants



Types of Memory

University of Essex

Short Term Memory

Rehearsal (Repeating information)

Long Term Memory

Implicit Memory (unconscious)

Priming (exposure that affects responses later)

Procedural (skills & tasks, how to do things)

Explicit Memory (conscious)

Semantic (Knowledge of facts, faces words, ideas & concepts)

Episodic (personally experienced events, facts)

Spatial (locations, layouts and navigation)

Interview Questions

Pre-planned interview questions relating to memory were prepared to guide the (semi-structured) interview. The questions are shown in Table 25. Additional exploratory questions were asked where appropriate to follow-up on participants' responses. Conversely, some questions were omitted if the participant had already addressed the relevant topic earlier in the conversation. These specific questions were designed to help answer the research questions (described in the chapter introduction).Table 25. Qualitative Interview Questions

Questions
1. Is there anything specific you struggle with regarding your memory?
(referring to the slide on the screen)
2. Are there specific types of objects or events that are particularly hard for you?
3. Can you describe a significant life event in your past please?
4. Can you picture a future event, like a dream holiday and describe it?
5. How is your old / new memory different with LC?
6. Overall, how has LC affected your memory?
7. How does this affect your daily life, including work and social life?

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8. Is there anything you find particularly difficult about your memory changes?
9. How has your spatial memory and ability to navigate changed? Can you give examples?
10. How do you recall environments and navigate (e.g., planning routes, locating objects)?
11. How has your procedural memory (remembering how to do things) changed? Can you give examples?
12. How has your episodic and autobiographical memory changed? Can you give examples?
13. Can you remember where you were during a recent Royal Family event? (e.g. Queen Elizabeth II passing, King Charles III's coronation)
14. How has your semantic (factual) memory changed? Can you give examples?
15. How well can you recall information from memory?
16. How has your short-term memory changed?
17. How has your long-term memory changed?
18. Can you recall what you had for dinner a few evenings ago?
19. Have you developed any techniques to support your memory?

Positionality

To situate myself within the context of this research and enable transparency, I have taken the opportunity to reflect on how my positionality and epistemological standpoint may influence the interpretations of the data collected in this study. This study was informed by a critical realist, contextualist epistemological standpoint. This standpoint considers the accounts by pwLC to reflect their experiences of cognitive difficulties while recognising these are interpreted and shaped through different contexts.

Over the last three years I have spent extended amounts of time with pwLC, both academically and through engagement and advocacy work. This has inevitably shaped my view and informed my approach to this qualitative research. During to my involvement with the LC community, I have been exposed to personal stories of the stigma pwLC are facing and the difficulties that challenge them trying to navigate these difficulties. Although I do not have direct lived experience of LC, the relationships with pwLC I have built through my research and community work have informed my deep empathy for individuals navigating the uncertainty and challenges. I have felt privileged to work so closely with this community, to try to provide some validation to the people who have shared their personal experiences. However, during the analyses of the data, I ensured these outside experiences did not alter my interpretations within. I did this by repeatedly rereading my notes and writing, to check with myself that themes were truly apparent in the data rather than preconceived ideas. Additionally, particular attention was paid to the phrasing used that may indicate my own bias and there were edits of my interpretations, to ensure more neural terms. Furthermore, referring to the interview transcripts allowed me to check that themes had not been focused on more than others. . I approached this research with responsibility to represent these experiences authentically and ethically, while keeping my own bias in mind. I have worked to ensure a balance between compassion and empathy but ensuring objectivity during the analysis. I have worked to ensure that participant voices remain at the heart of the analysis, the interpretation and the findings. I view this research not only as an academic contribution, but also as part of a broader effort to advocate for pwLC. Further reflections regarding my positionality are included in the discussion.

Procedure

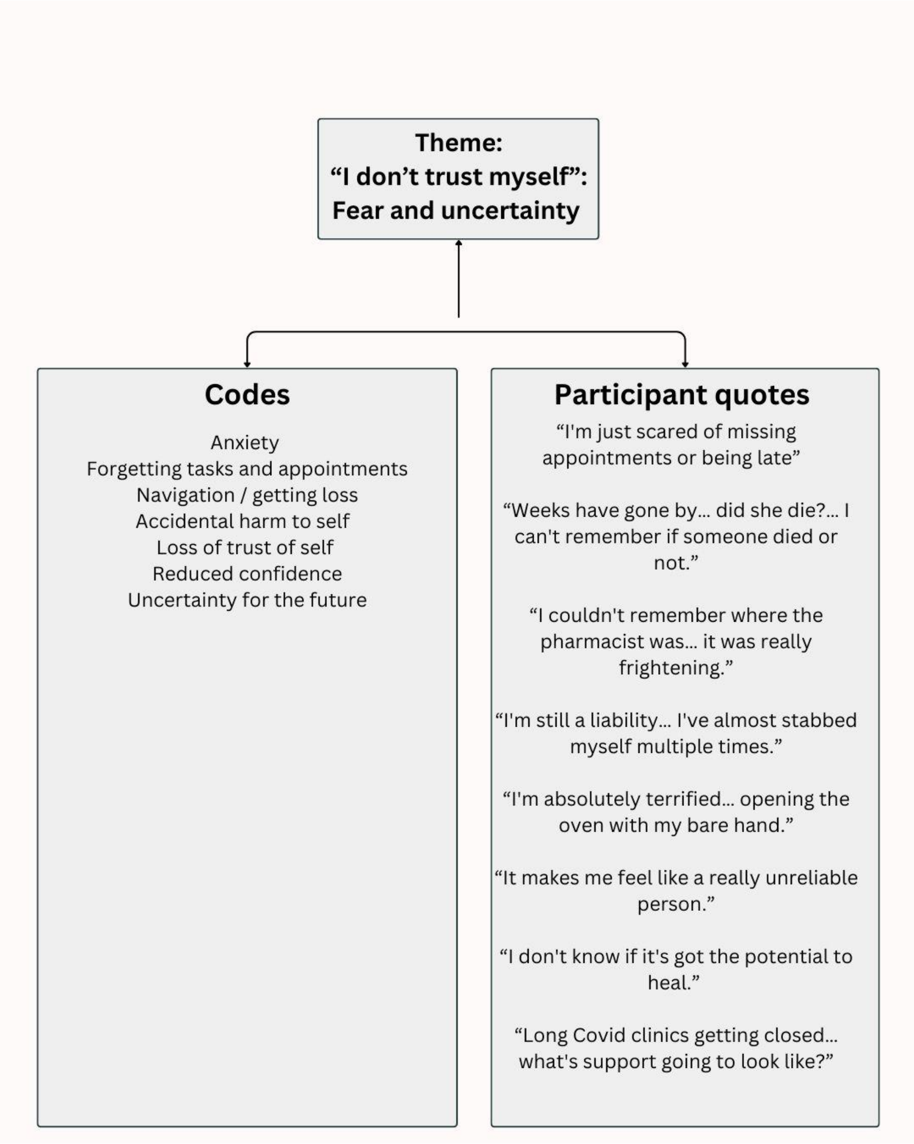
Participants who demonstrated interest were sent the participant information sheet detailing the study aims. To accommodate various times for data collection (e.g. daytime slots, evening slots, weekend slots), an online booking system was set up using Calendly. Participants were able to select a preferred slot that was convenient for them to attend the interview via Zoom. Each session was allocated a one-hour slot; however, participants were informed that to minimise cognitive burden they could choose to do this as either a single interview or they could split it into two shorter interviews if required. Only one participant requested to split the interview. Participants were given the choice to have their camera on or off on Zoom for the interview as video recordings were not required. Participants were given time to ask any questions about the research prior to the interview starting and after the interview had finished.

Participants were asked to complete a digital consent form via Qualtrics. Once the consent was confirmed and the participant was ready to start, the audio recording of the session was started. The interviews followed a semi-structured format using the prepared questions. Each interview began by asking the participant to look at the ‘types of memory’ slide, and to identify any areas of concern that initially jumped out to them before working through the set questions. Once the interview was finished, the participants were thanked for their time and the audio recording was then stopped. After the interview, the participants were sent an email providing them with a personalised link to complete the questionnaire via Qualtrics. Zoom’s transcription service was used; however, the transcripts were checked to ensure accuracy. The audio files were deleted once transcribing was finished. Each transcript was given a participant number.

Analysis

Each transcript was read through multiple times. During this phase, points of interest and notable phrases were highlighted to begin identifying recurring ideas and experiences. During this time, reflective notes were completed to document emerging thoughts during the reading process. Reflexivity felt particularly important given that the researcher had previously conducted a thematic analysis of survey responses from pwLC, therefore these prior analyses had the potential to shape expectations and influence the analysis of the current interview data. Keeping notes to acknowledge and examine any preconceptions helped to distinguish between data from the transcripts and interpretations that were potentially influenced by the earlier analyses. Following this the formal stages of thematic analysis, as outlined by (Braun & Clarke, 2006) began. This process guided the progression from initial coding through to the generation and refinement of themes. The analyses were conducted manually using highlighters and mind mapping to visualise codes and later themes, these are displayed in Figure 37.

Figure 37. Example of a coding tree



“I'm just scared of missing appointments or being late”

“Weeks have gone by… did she die?… I can't remember if someone died or not.”

“I couldn't remember where the pharmacist was… it was really frightening.”

“I'm still a liability… I've almost stabbed myself multiple times.”

“I'm absolutely terrified… opening the oven with my bare hand.”

“It makes me feel like a really unreliable person.”

“I don't know if it's got the potential to heal.”

“Long Covid clinics getting closed… what's support going to look like?”

Results

Characteristics

All interviews were conducted remotely on Zoom between December 2024 and March 2025. The duration of the interviews varied ranging from 18 to 81 minutes, with an average length of 40.80 minutes (*SD* = 17.11).

The first section of the results section uses qualitative data to describe characteristics of the LC sample. The results of the autobiographical interviews are analysed quantitatively and lastly the thematic analysis is presented.

Participants had contracted Covid-19, the infection that they believed resulted in their LC, between March 2020 and February 2023. All participants confirmed they had been formally diagnosed with LC and had been living with LC for 24 to 58 months, with an average of 39.44 (*SD* = 11.48). The participants reported between three and 25 long lasting LC symptoms, with an average of 11.08 (*SD* = 5.13). These symptoms ranged from fatigue to tinnitus. The quality of life and fatigue scores provided by the participants are shown in Table 26, alongside the scores from the Assessment Three, which was closest in time to the current study. The samples do not significantly differ in their scores (QOL; *t* (63) = 0.39, *p* = .695. Fatigue: *t*(63) = –0.39, *p* = .698.) and therefore any conclusions from this study can be generalised to all participants tested throughout this thesis.

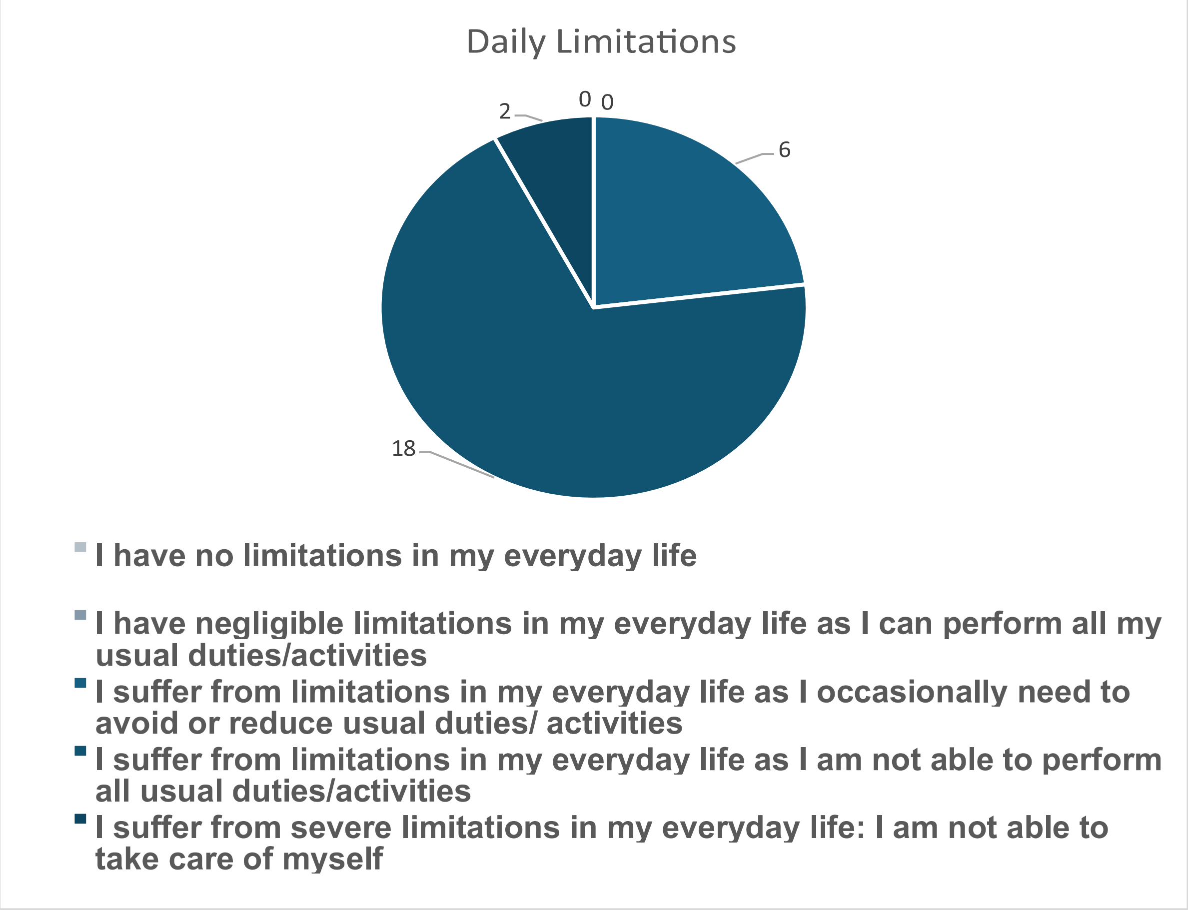
Table 26. Quality of Life and fatigue scores

	Interviews **N = 26** **M (SD)**	**Assessment Three** **N = 39** **M (SD)**
Quality of Life	57.52 (14.09)	59.15 (17.68)
Fatigue	25.52 (6.18)	24.82 (7.62)

Daily Limitations

The daily limitations that were captured in the previous chapter, were used for this sample of pwLC during this study to help to understand the daily impact of LC on this group of participants. The results, which can be seen visually in Figure 38, demonstrate that most of the sample responded to the need to reduce or avoid activities due to LC. However, they were able to remain independent.

Figure 38. Daily Limitations



LSCI

The variables that were previously used to calculate the LSCI scores were used during this study to provide each participant with a LCSI score. The scores ranged from 33 to 86, (M = 54.42, *SD* = 13.98). A median split was performed to categorise participants into ‘Mild’ or ‘Severe’ LC. Twelve participants were categorised as having ‘Mild’ LC, whilst 14 participants were categorised as ‘Severe’.

Short-Term Memory (STM)

When the interview commenced, the participants reflected on their memory using the slide as a prompt. Many participants (69%) immediately declared issues with their short-term memory,

> *"The short-term memory seems to be a problem for me" (pwLC1), "I definitely struggle sometimes with short term in that even just going from one room to another" (pwLC4), "Short term I definitely struggle with*" (pwLC8), and *"short term memory is definitely problematic. I'm gonna tell you that now*" (pwLC21)

This suggests that for some pwLC the ability to hold information for brief periods is challenging. Others compared their STM to their previous abilities,

> "*I guess my short-term memory isn't what it was certainly. A lot of, I get a lot of memory issues across that whole lot [*looking at the prompt slide] *to be honest. Short term is probably the one I've noticed the most"* (pwLC20) and *"yeah my short-term memory is not brilliant now, so it just takes me a little bit of time to process"* (pwLC2), highlighting how LC had impacting their STM functioning.

Many of the concerns described and the reflections provided, attribute STM difficulties to rehearsal processes, which is vital for holding information for brief periods (Nadel & Hardt, 2011).

> "*That sometimes…just repeating information is problematic. So, I just haven't heard it and I, I say to people like, I think it's more overwhelming attention and I say to the children, I can see that your mouth is moving and you're making*

> *noise. But I just can't actually interpret what you're saying, processing it"* (pwLC15) and "…*the short-term memory like rehearsal repeating information and there was a period of time where I struggled. I do still struggle a little bit, but again not like I did*" (pwLC24).

Attention, which is required for effective memory rehearsal (Oberauer, 2019), was difficult for some participants who reported an inability to multitask (pwLC12 and pwLC18) and ability to maintain concentration "*I still struggle from like…. and concentration. So, I can't focus on things for long periods of time. I need to have regular breaks, because I get start getting really bad headaches or feel foggy and blurred"* (pwLC24) which may contribute to their difficulties with STM. One participant directly acknowledged their inability to give tasks their attention, *"I guess it's just that kind of being able to have enough attention, enough to go from short term to long term just seems to be something that's kind of affected like I can either do the thing or remember the thing but not both" (*pwLC18*).*

Participants described having difficulties with processing large "*chunk*s" of information (*N* = 2) and struggling to follow and retain contents of long conversations (*N* = 4) and "*sometimes the repeating of information is problematic*" (pwLC15), all of which may suggest limitations in their memory capacity, and which may contribute to their inability to process information. One participant expanded that they felt had impaired thinking time:

> "*I suppose when people are explaining things to me, it's difficult to, like I hear the words but to process them and keep them in mind to understand what is*

> *being said…=, it takes ages to translate it in my brain and then comprehend what's being said to then formulate a response, there is a definite lag*" (pwLC 21), suggesting slower cognitive processing.

Some participants described an inability to learn new things,

> *"I struggle to take it very much in the way of new facts, learning new things is quite hard for me now*" (pwLC5), another described "*its new stuff I struggle with…I can feel like, I'd be halfway through and forget. I can feel that fog coming in as well*" (pwLC2), while another said, "*and even at my best, my brain is completely lost, I don't have the capacity to retain*" (pwLC10).

The ability to learn new things depends on STM rehearsal to transfer information into LTM. Atkinson and Shiffrin (1968) suggest that rehearsal is key to embed memories into STM and these processing difficulties may hinder that process. Collectively these difficulties may suggest deficits in STM rehearsal in pwLC.

Participants gave examples of how their STM had impacted their everyday lives,

> *"so short term memory was one of the first things I noticed and like yeah, that was one of the things that caused me the most problems when I was still working like I couldn't remember"* (pwLC18) and "*an example this week, we have milk being delivered to the house …Completely forgotten and so my short-term memories have been affected because before this I would have remembered"* (pwLC25).

Other everyday challenges included difficulties with technology (*N* = 2) and inability to recognise faces.

Summary of STM

Just under 70% (*N* = 18) of participants reported STM difficulties. This manifested as concerns with attention, processing information and conversations, slowed cognitive processing and inability to effectively rehearse information. The participants provided examples of how these difficulties were impacting their daily lives from forgetting conversations and how to use technology.

Long-Term Memory

While direct LTM difficulties were less immediately reported by participants when the interview first commenced, this was further explored by looking at specific areas of long-term memory including procedural, semantic, episodic and spatial memory. For some participants, their LTM was described as the more reliable comparatively to their STM,

> "*My long term memory is way better*" (pwLC3*), "so long term memory is all right. I don't find that as impactful as the short-term memory. There's specific details that go and that's usually like the name of the cafe, or like the order that things happen in…it's the short term memory that has the most impact on my day*"(pwLC6), *"I think long term is a little better, I think short term I*

> *definitely struggle with"* (pwLC8), "*I would say my short term isn't as good as my long term*" (pwLC16) and "*my long term memory is it's okay, I'd say but sometimes it takes a bit of a reminder"* (pwLC21).

Others described that they did not think there was any impact to their LTM functioning,

> "*My long term memory is crystal clear. And I randomly remember things from my childhood that I haven't even thought about"* (pwLC22), "*I don't think my long-term memory is recall is affected at all. I can remember things in the same way as I did before covid*" (pwLC23) and "*yeah, it feels like those [LTM] are kind of unchanged"* (pwLC18). One participant commented how her LTM was dependent on symptoms "*I think my long-term memory probably is a little bit better than my short term, but if I'm going into post-exertional malaise or in a crash then the long-term memory is affected quite heavily, as well"* (pwLC12).

Others reported there were noticing differences in their LTM such as "*less detailed* " (pwLC18), "*harder to access*" (pwLC12 and pwLC13), "*much more hazy and foggy*" (pwLC9), "*harder to get things to stick into long term memory*" (pwLC8) and yet other participants indicated their LTM had worsened "*I know I have a problem with that now [LTM]. A conversation I had with my mum yesterday was about that. I remember when we went. I've got no, I literally have no recollection of what she was talking about where we went, what we did, no recollection of it"* (pwLC14) and "*probably the* *long-term memory is more affected now*" (pwLC13). This may suggest that although the LTM difficulties were not initially as apparent as the STM ones, they have become problematic for some.

Conversely, other participants reported improvements,

> *"…whereas my long-term memory is really strong. Still, it wasn't, it wasn't at the start of infection, but it is. It has recovered"* (pwLC5) and "*Now that I am much further into my recovery it's a lot quicker, I'd say is the main difference"* (pwLC21) and "*I think my long-term memory has got better since what it was sort of back when I got first diagnosed"* (pwLC25) suggesting that previous difficulties have become easier.

Others discussed the difficultly in assessing their LTM,

> *"I haven't been digging back into my memories lately. But yeah, I would say that there, there are gaps in my memory and the memories of my past events, it's just difficult…It's so tricky" (pwLC17) and* "*it's really difficult to explain what I think happened to my memory, because it's like I can remember that there are lots of things I can't. I suppose that have gone. But I can remember most things, but it's more about, it's about being able to access them (LTM)"* (pwLC10).

One participant spoke at length at the work they had done in an attempt to access their LTM

> "*I think I've actually done quite a lot of mental work on trying to make connections. … and so I think I've done quite a lot of connecting with those really old memories, but it does feel like I've had to really do that work*"

> (pwLC15). These quotes may suggest that while participants can remember LTM, they differ in their ability to access that information, some LTM can be accessed , while other LTM cannot.

To explore recent long-term memory and the ability to retrieve information, the question ‘could you tell me what you had for dinner a few evenings ago’ was included. Just over half of the participants were able to recall what they had eaten in the previous days, however there is no way of knowing if this recall was correct, with one participant stating their successful recall was due to their workings out “*yes but only because I'm working back through the days. I know roughly what I've eaten”* (pwLC20). Two participants responded, ‘probably not’ and one added, *“which is surprising for me until a few years ago, I would have vividly remembered exactly how the meal was cooked and what it tasted like and its appearance and whether I added any sauce to it or whatever”* (pwLC1), highlighting a contrast to their previous memory. Nine participants confirmed they were either ‘not sure’ or were unable to recall what they had eaten, “*No, that's something I struggle with a lot…No, I don't think I can”* (pwLC18) and “*I could tell you yesterday. But yeah, noo further than that”* (pwLC12), suggesting that for some individuals recent memory retrieval and encoding remains problematic.

One participant commented that they were able to remember their meal if they were able to connect the memory onto something else, which may be result of cued recall or encoding

> *“Hmm, yes, I can, because we had, we cooked gammon as a roast, and then we had gammon and eggs on Monday… But that's a bit hit and miss, if I hadn't had that to hook it on, I don't think I would have remembered*” (pwLC9).

Similarly, others said were more likely to remember their meals when these were different or outside of their normal routine,

> “*Probably only because of the events of this week. Really stuck in my head with the emergency situation on Monday. I can tell you that I made a beef stew and I had that in the slow cooker luckily”* (pwLC22), “*so Thursday probably because it was out, so they put a spread on for us, so that was really nice….but that was kind of like a special meal”* (pwLC25) and “*I know what I had on Monday…so that was a special event, because we don't do that very often. So, I do remember. But no, I can't remember what I had for dinner any other day of this week”* (pwLC21).

Implicit Memory

Procedural Memory and Priming

Some participants reported disruptions in implicit memory, particularly with procedural memory, the unconscious ability to carry out learned tasks and routines (Knowlton & Greenberg, 2008). Many expressed difficulties with following instructions and tasks that require multiple steps. Which may suggest a breakdown in remembering sequences of familiar actions,

> "*Procedural skills and tasks are a big one for me, it's the order of things, like almost every day if I go to get into the car, I try and get in before I have clicked to unlock it, every single time, why am I doing this?! Theres been times when I go to put the laptop on and I'm like how do I even turn it on….and driving, I can't remember how to change gear, that was quite scary*" (pwLC 15).

This is similar to what is observed and reported for dementia patients (Roll et al., 2019). Sequencing involves prospective, future memory as you need to think of the next step but also working memory to hold the current step in mind (Baddeley, 2007). Other participants spoke about how they struggled with ordering tasks and linking pieces of information coherently "*it's not second nature, there'll be points when I get stuck… if I get disturbed in the process (making coffee) and I come back to it, then I don't know where I was and I'll have to start from the beginning, manually do that process*" (pwLC6), which may indicate an impaired ability to access procedural memory. Furthermore, this may also reflect executive dysfunction. This description of trying to process information "*it's like my brain just shuts down*" (pwLC3) highlights the cognitive fatigue associated with carrying out tasks that previously relied on automatic processing. In terms of priming, several individuals reported forgetting conversations, which suggests a failure of the subtle memory traces that normally shape later responses.

> "*if I am introduced to them, by the time I have got home I would have forgotten their names*" (pwLC11), "*even an hour or two later, I get scared I'm gonna forget*" (pwLC14), "*and I do more saying to people, please will you*

> *remind me, because I probably will forget and I've found strategies for saying, I know you've talked about it, please remind me*" (pwLC15).

These difficulties may indicate that core components of implicit memory may be compromised in some pwLC. While implicit memory in pwLC has not been extensively explored in pwLC, there is research to suggest that the consolidation of procedural memory is more affected, compared to the acquisition of memories in pwLC (Almeria et al., 2020; Crivelli et al., 2022; Fiorentino et al., 2022; Schou et al., 2021) (Llana et al., 2022).

Explicit Memory

Semantic Memory

Many participants described challenges consistent with impairments in semantic memory, the system responsible for storing general world knowledge, facts, concepts and language (Nadel & Hardt, 2011). Forgetting facts from the past was a common and impactful complaint, which suggests retrieval difficulties rather than a complete loss of information.

> "*I almost feel like there are facts that I knew that I might have gathered over 44 years of life. But I now can't really get them out of the archives unless I've revisited them since having Covid. So, you know, even things like things that children know like, what's the world's fastest animal? What's the longest river? I feel like I would have known those things, and now I don't, unless they've come up in the last few years since Covid….I would have assumed that*

> *knowledge would be there. But it wasn't, and it is now, but not as concrete as it was*" (pwLC15).

Word finding difficulties were self-reported by 65% of participants ($N = 16$) throughout the interviews. Participants shared how they were struggling to speak fluently, access the correct word and or term, which could also suggest executive dysfunction, and it was referred to as "*having a mouthful of marbles"* by pwLC4. Similar word finding problems have been previously highlighted in LC research (Guo et al., 2022). When trying to describe this process, a participant shared, *"it's like it floats through my brain, and then off it goes*" (pwLC9) capturing the unstable nature of access to language. These word finding difficulties were exacerbated by fatigue "*it is much worse when I have poor sleep*," (pwLC26). The difficulties of fatigue were echoed by 10 other participants (38.46%).

Other difficulties were reported included difficulties with spelling, which could indicate phonological issues.

> "*I had almost perfect spelling, like, yeah, had almost perfect spelling. There wasn't a word I couldn't spell….I'm not confident"* (pwLC15), and difficulties forming concise speech. *"In terms of editing information or like summarizing things to you for instance, I can't do that anymore….Whereas before I would have very easily been able to just really get to the essence of what I'm trying to say. Whereas now I can't filter it, it's almost like being drunk. That's kind of what it feels like. It's like, not that I've been drunk for a very long time, but it's like it. It is that kind of feeling of like everything just kind of blurts out and I've*

> *got little control over that kind of thing*" (pwLC10), which may also suggest executive dysfunction.

Concerns with reading were expressed by some participants which may reflect additional challenges where typically automatic process such as parsing words or sentences (I.e. procedural memory) are more effortful. However, this could also be language issues, rather than a memory problem. For one bilingual participant, mixing languages has become a problem since living with LC,

> "*I'm mixing languages, so half of the word can be in English and the other half can be in my native language and that's something that I haven't had before Covid and I think a lot of it is memory affected…. But yeah, I think that is because the long covid community is so international so you're speaking a lot more English. And I also have a lot of English-speaking friends…..But yeah, it. It is a bit of a struggle to switch, especially if I need to do it fast like up and then speak Norwegian and then midday speak English and then going back to Norwegian in the evening. It's just like, oh, I need a minute to adjust my brain"* (pwLC12). Another bilingual participant said "*I'm not speaking English so much, we speak Spanish at home and even though I watch TV, but I feel like I'm losing all my fluency in in English, yeah, that's more one of the things that I find more problematic. It's not only fluency, it's just sometimes I know the word, and I just can't find it inside my brain and then, maybe two hours later, the word just pops up out of the blue without any relevance to what you're doing at the moment, or anything like it"* (pwLC17).

Other difficulties including problems recalling names were reported by a third of participants (*N*= 8),

> "*I'm terrible for names now and that was never a problem before. So that is a real thing I sort of recognize"* (pwLC4) and "*personally, I have issues with names, gotten worse as I've gone along. I feel like it's gotten worse"* (pwLC16).
>
> *."*

This specific semantic problem has been previously documented (Burton & Bruce, 1992). Processing numbers were also described as more difficult,

> "*I won't remember precise amounts whereas I used to… I'm constantly having to look things up, which is really tiresome"* (pwLC13) and *"…Yeah, it was a bit of a shock, because I've got three children, and I've done like 10 times tables with both children all the way up to 12 times tables, and then with the third one, he's coming along now, and he started to do like twos and threes and fives, and suddenly I'm like Oh, gosh I don't know, Oh, I don't! How do I not know that?....but so numbers are not clear as clear as they were"* (pwLC15).

The difficulties processing numbers may demonstrate an inability to access stored semantic knowledge and elements of conceptual knowledge. Previous research has suggested that semantic memory is impaired in pwLC (Almeria et al., 2020; Crivelli et al., 2022; Fiorentino et al., 2022; Schou et al., 2021) which is consistent with temporal hippocampal damage findings following Covid-19 infection (Moriguchi et al., 2020). It has been suggested this is similar to what is seen in patients with neurodegenerative diseases (Henry et al., 2004).

Episodic Memory

Some participants reported disruptions in episodic memory. These issues were often described not as a total loss of memory but, again, as a difficulty in accessing past experiences without significant effort or external cues. One participant explained that "*connecting with those really old memories... does feel like I've almost had to sort of dig, dig out a new pathway to get to those things back*," (pwLC15) suggesting that while the memories may still exist, the retrieval process may be impaired, consistent with episodic memory disruption. Another participant reported inconsistencies in episodic memory, "*I think I think that's one of the things I've noticed is that I have forgotten some details of my life as well"* (pwLC26). Gaps in autobiographical memory may suggest to reduced ability to recall episodic memories, particularly in the spontaneous recall of past experiences even when long term memory storage itself may remain relatively intact. Episodic memory impairments have been previously reported in pwLC (Zhao et al, 2022), who made false alarms during episodic object orientation task which was suggested as a potential deficit in binding information in memory.

Maintaining a coherent sense of time was problematic for some participants, *"Yeah,*

> *concept of like time and processes is definitely what I struggle with the most*" (pwLC6), "*but my perception of time is different. ….I don't really have a perception of time anymore" (pwLC7)* and *"and also, I feel that my memory of*

> *time has been affected. Like the feeling of what I did last year it's probably no different to what I did in say two weeks ago, Like the concept of time that's very weird as well" (pwLC22)*

Spatial

Spatial difficulties were evident with several participants reporting disorientation, difficulty navigating environments and increased banging into objects in their environments. When discussing spatial awareness, one participant said

> "*I'm clumsy. I'm really clumsy like I collect transformers and so there's certain more basic ones I can manage with….very frustrating…outside of the flat I struggle, and sometimes I really really struggle crossing roads really. And there's been a few times I've just had to stop and go okay, I'm trapped here like a small child, and I get dizzy spells still"* (pwLC5)". This could also be reflecting executive dysfunction.

Another reported spatial judgement issues.

> "*Not but not so much recently, so I did an awful lot of walking into walls. In fact, we ended up having to buy me elbow pads that roller skaters use because the bruising on my arms was getting so bad. The joints were getting painful because I just smacked them so often, going through doors and stuff like that"* (pwLC20).

Some participants described experiences of getting lost, sometimes in places they previously knew (pwLC5, pwLC12 and pwL13), and others reported forgetting the locations of specific places (pwLC10 and pwLC15). This lived experience demonstrates how frustrating this can be in everyday life,

> *"…and also, I need to be very familiar in the location. So, if I'm in a new location, I can't remember where I'm supposed to go like in a shopping mall, for instance, if I'm going from one store to another. I don't remember how I got there, so I always need to go an extra round to end up where I was, because my brain is not capable of going right when I'm supposed to go left, for instance. I feel like when I'm out and about, my memory just shuts down like"* (pwLC12).

This further highlights challenges in spatial layouts and environments and how such challenges can impact people's independence. These accounts also suggest executive dysfunction i.e. lacking ability to problem solve. While less reported than other deficits, these disruptions had a noticeable impact on daily functioning and independence for those affected and these difficulties may suggest issues with retrieving spatial information and executive functioning, which has previously been reported in pwLC (Ahmed et al., 2024; Ferrucci et al., 2021).

The participants were asked to recall from their long-term memory a past national event 'can you remember where you were during a recent Royal Family event?' (e.g. Queen Elizabeth II passing, King Charles III's coronation). Nineteen participants (73.08%) could access these long-term memories, two participants were unable to recall, one responded “vaguely”, and four others were unable to recall a recent royal event but spoke about ones from further back in time, suggesting they were not disinterested in the topic but their LTM was easier to recall. One of the participants who was unable to recall the details did not attribute this difficultly to LC. They responded,

> *“No, I definitely wouldn't….I wouldn't have the faintest idea what had happened on any major event, really. I think I might have always been like that” (*pwLC1).

For some participants as well as being a national event, the period of time they recalled also held some personal significance, “*The Queen's last Jubilee before she passed away was the day I got Covid really bad, so I do remember that that to me has now become a life, changing event. I can actually remember” (*pwLC11) and “the *Jubilee was my 1st Covid infection, a negative memory” (*pwLC17). This is not unusual as national events can often act as a landmark for autobiographical events in memory (Brown et al., 2009). Additionally, these links between personal and public memories are often observed where there has been a severe effect on lives (Brown et al., 2009).

Another example of a severe effect on daily life and links to a landmark national event, comes from one participant who used this vivid description to recall not only the event but their own feelings at the time,

> *“Though the coronation I remember really vividly because I didn't feel very well, and I'd wanted to sort of make it a bit of fun, and my husband was at*

> *work, and the long Covid, was really bad that day but I just was really wiped out. And I was thinking, like other people are doing like everyone's doing their little thing with their like meeting up with their family or they've made like an afternoon tea, or I don't know people were having fun because it was the coronation. And I was just watching it on telly, thinking I've got no energy to go make myself a cup of tea really…. And the guy who was the right-hand man to King Charles was actually the guy that I worked with. When I knew him in my twenties and so it was sort of a bit surreal. That part of me was like it's exciting that I know him and I recognized his mannerisms. I thought 'I've cleaned his toilet!' and at the same time thinking, 'wow, look where your life has led you to' like you are basically, you could see he was reassuring the king, and I was like, I know I just feel like death like. Where is my life going to go. I was watching that thinking that's amazing and then at the same time feeling so remotely removed from that that I'm just in a darkened room on my own, watching it without the energy to make a cup of tea, how different our days are! And so, it was like a real kind of bittersweet memory. The reality, I am like half dead watching you"* (pwLC15).

This poignant statement reflects the participants ability to not only recall the national event but also captures the emotional complexity of that event. The loss of socialising during the event is apparent but also the recognition of a colleague led to some difficult feelings with reference to their past identity and their current limitations. This resulted in the participant switching between awe at their former colleague to grieving for their former life throughout the narrative. Research has demonstrated that the arousal induced by emotional events has also been shown to facilitate subsequent memory retrieval (Cahill et al., 1996), which might underlie this person’s ability to retrieve the episode in detail.

Some participants were unable to recall a recent royal event but spoke about previous events dating further back in time, “*I don't remember one of the recent ones*” (pwLC14). One participant commented

> “*See, now, this is silly, because I can remember the silver anniversary. Back in ‘77, because when I was little, they had like a big open day on the sports fields where I live and they had children's races and things. And I don't remember much detail of the day, but I definitely remember being there, and all of the children got one of those commemorative coins. Oh, yeah, taking part in a race. So yeah, I remember that” (pwLC11),* which indicates their long-term autobiographical memory is intact.

Some participants spoke about remembering when Princess Diana had died,

> “However*, I could probably tell you in detail about Princess Diana's funeral* (pwLC22), “*I remember very, very clearly where I was when Diana died. I was at a party, and we saw the breaking news in the early hours in the morning. So, I really really remember that really clearly. I mean the latter ones I don't actually remember*” (pwLC13), “*I can remember when Princess Diana died. Yeah, that's sort of that's clearer than when the Queen died, really. When, but maybe because that was more, everyone was shocked, weren't they? And it was a massive event. So yeah, and I've recalled it as well, since it was a bit because I remember I was staying at my sister's house, and she said, oh,*

> *Diana's died, and I thought she was talking about a plant. So, I suppose you remember those odd things"* (pwLC9) and *"I'm not a Royalist but particularly I did because I grew up when Diana was kind of you know, there. So, when I was 11, I had all the scrapbooks and everything. I've still got them actually. But yeah. So, when she died, I remember, do you want me to actually tell you... "(*(pwLC4).

Some of these recalled memories are like those which are often referred to as flashbulb memories (Brown & Kulik, 1977), where people can remember their circumstances when they learned the news of the event. Despite the timelapse, as Princess Diana died in 1997 compared to the Queen Elizabeth II's passing in 2022, these participants were able to recall these memories in detail. This may be due to the length of time before being unwell that the memories had consolidated, compared to those who expressed poorer recall in recent events when they had been unwell, again suggesting encoding issues.

Some participants who confirmed they could recall spent extended periods of time housebound and due to this inferred their recall about their location was based on assumptions,

> "*I suppose the kind of since Covid memory is also a bit skewed because I'm mainly housebound, so it's like odds are I was here which would skew it a little bit, but I can remember being on the sofa and stuff around the Queen dying, and that sort of thing that kind of lead up to that but it is since I've had covid, it does feel like those things are fuzzier"* (pwLC18), "*The recent events. I know*

> *I've been at home for all of them, because I've been ill with LC, and I know that I have talked about them, and say, watch the news about them"* (pwLC22) and *"When the Queen died, we were at home and then the coronation. We were at home again. We spent a lot of our time; that's just chronic illness living for you" (pwLC3).*

An important factor to consider is that the recall responses may have been subjective based on whether the interviewee had any interest in the royal event or the royal family as one participant pointed out. Some participants did acknowledge this,

> "*I don't remember where I was, but I remember that my sister still lives in London, and my mum was visiting my sister at the time, and they like sent a photo to the family WhatsApp group with kind of lots of flowers left outside Buckingham Palace. So, and I remember, like the news stories about the queues to see the body and but I guess yeah, I'm not particularly interested. My sister is a very big fan of the Royal family, so I guess that's why they went. Maybe that's why I don't have strong memories" (*pwLC8) and "*I am not a Royalist whatsoever. So, I, yeah, it wouldn't be like a big life event"* (pwLC23).

Previous research suggests that learning about public events is based upon motivation to know (Eveland,. 2001). However, these participants whose motivation was low, were able to recall some details regardless. Other participants recalled different events outside of the recent examples that were provided alongside the question. These included Prince Charles getting married (pwC10) which occurred in 1981, the 9/11 terrorist attack in New York City (pwLC26) in 2001, the 7/11 London bombing (pwLC25) that happened in 2005, Prince William getting married (pwLC20 and pwLC21) in 2011 and Prince Harry getting married (pwLC4 and pwLC25) which took place in 2018.

Summary of LTM difficulties

While the impacts of LTM difficulties were initially less immediately recognised by participants compared to STM difficulties, the exploration of specific areas gave indication of some challenges. While some participants reported subtle differences in their LTM, others reported how this had improved, and conversely others suggested their LTM had worsened. These conflicting reports of function, align with previous findings within this thesis that the patterns of recovery of cognitive functioning are not linear. Recent LTM retrieval abilities were mixed across participants. Meal memorisation appeared to impact recall abilities. Procedural, episodic and spatial memory was challenging for some pwLC. However, the concerns with semantic memory, specifically recalling facts and names alongside word finding difficulties were problematic for a large portion of the participants. The lived experiences of LTM difficulties provide some insight into the impact of LC on how day-to-day function from being unable to retain information, to getting lost and independence being compromised.

Adapted Autobiographical Interview Analysis

Past Memory

To further explore autobiographical memory, we included a question which aimed to capture the participants ability to describe in detail a past memory from their life. This question was given without cue and participants could choose any event they wanted to recall.

For this question there were 25 responses as one participant could not think of an example to provide. The minimum number of words used to describe a significant life event was 72 and the maximum was 1020. The average word count was 377 (*SD* = 242.78) and there were a variety of topics that people chose to share: Work-related significant events such being made redundant (*N* = 1), career highlights (*N*= 2) and moving abroad for a new job (*N* = 1), education-based events such as graduation (*N* = 2) and getting into a school of choice (*N* = 1), special holidays (*N* = 2), childbirth (*N* = 3), getting married (*N* = 2), attending a wedding (*N* = 1), meeting a partner (*N* =1), moving home (*N* = 4), days out (*N* = 2), birthday celebrations (*N* = 1), losing a loved one (*N* = 1) and reinfection of Covid-19 (*N* = 1). Autobiographical memories have been suggested to indicate a directive function of self or identity (Bluck et al., 2005).

The adapted autobiographical recall task was selected specifically to distinguish between episodic and semantic components of memory. By using the autobiographical interview framework (Levine et al., 2002), the analysis allowed for distribution between episodic memory and semantic memory as described below.

Each extract was scored into different categories (Levine et al., 2002). Details were categorised into two groups: internal (episodic) and external (semantic). Internal details were those directly relating to the main event that were specific to time and place. Internal details were separated into five categories, the event, place, time, perceptual details and emotions / thoughts. External details were those that were more relating to semantic knowledge and were separated into four different sub-categories: other events (outside of the one that was being discussed), semantic details such as general knowledge or facts, repetition and other details which included editorialising.

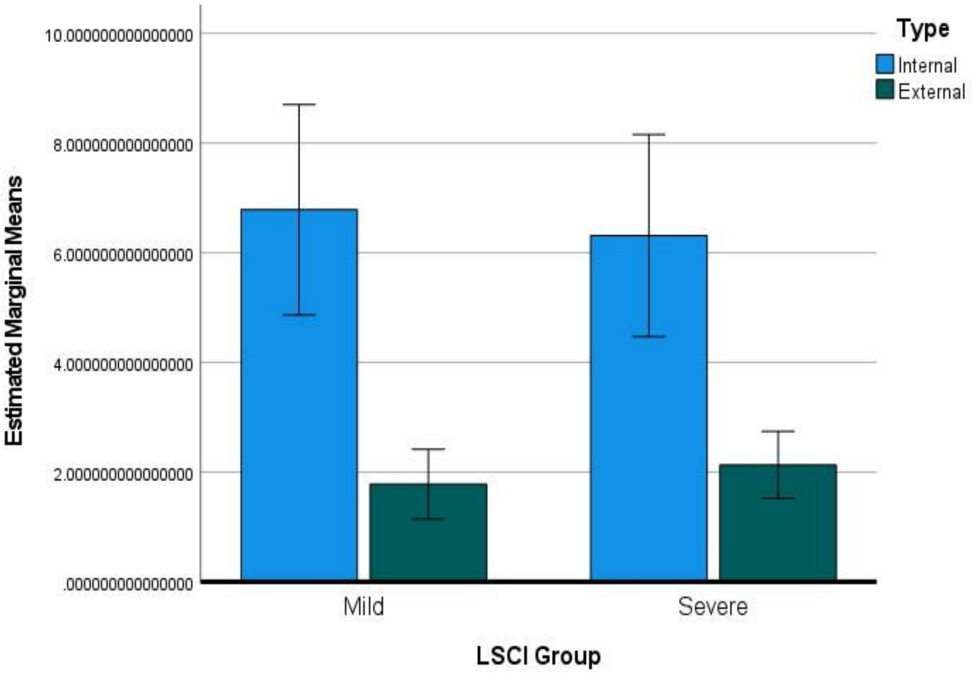
Each category was tallied and summed to make a total internal and external score for each extract. Next, the internal and external scores were each converted into ratios of the total word count for each participant to account for variability in total verbal output. This analytic approach is recommended as participants were not timed for this question, thus the number of words in their responses differed. Specifically, this was calculated as (total internal details / total verbal output) X 100 (Levine et al., 2002). The same calculation was done for external details. Multiplying the ratio by 100 provided a percentage to allow for comparison across narratives of different lengths. This was to ensure the scores reflected proportional memory content rather than differences in total words. Due to time constants, all extracts were scored by the primary researcher only and therefore inter-rater reliability was not confirmed.

Firstly, a paired samples *t* test explored differences in proportion of internal and external total output and there was a significant difference, *t* (24) = 7.54, *p* = <.001, *d*

= 3.03. PwLC produced significantly more internal details (M = 6.54, *SD* = 3.15, 95% CI [5.23, 7.84]) than external details (M = 1.96, *SD* = 1.05, 95% CI [1.52, 2.40]).

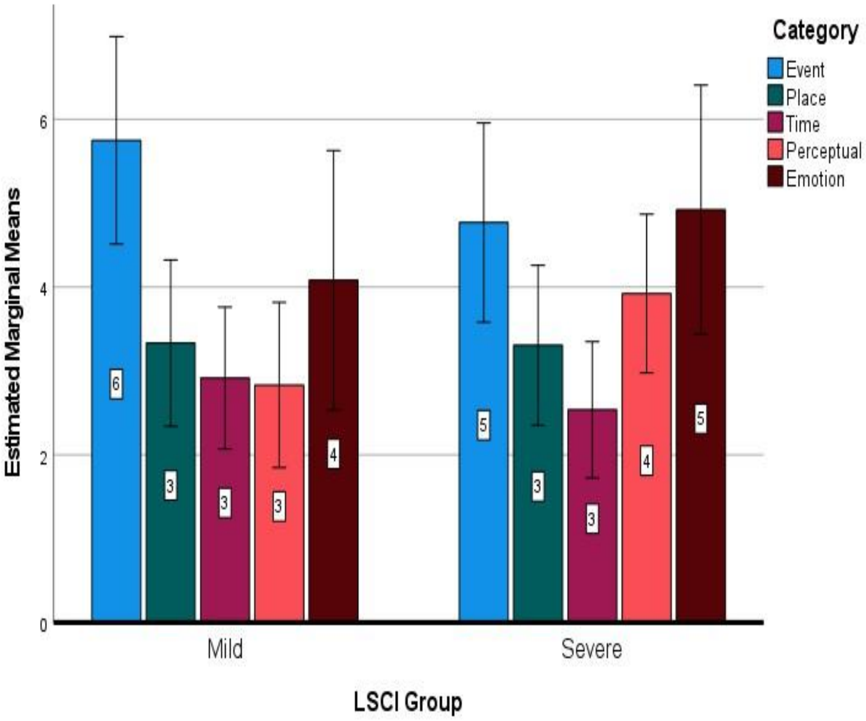
A mixed ANOVA was conducted with LC severity (Mild vs Severe) as between subject factor and type of recall (internal vs external) as within-subject factor, applying the Greenhouse-Geisser correction. There was a significant main effect of recall type, (*F* (1.00, 23.00) = 55.91, *p* < .001, *ηp²* = .709), as illustrated in Figure 39. However, the interaction between recall type and LC severity was not significant, (*F* (1, 23) = 0.45, *p* = .511, *ηp²* = .019). This suggests that the number of internal and external details did not differ with LC severity.

Figure 39. Mean ratio of internal and external total verbal output for both LC severity groups.



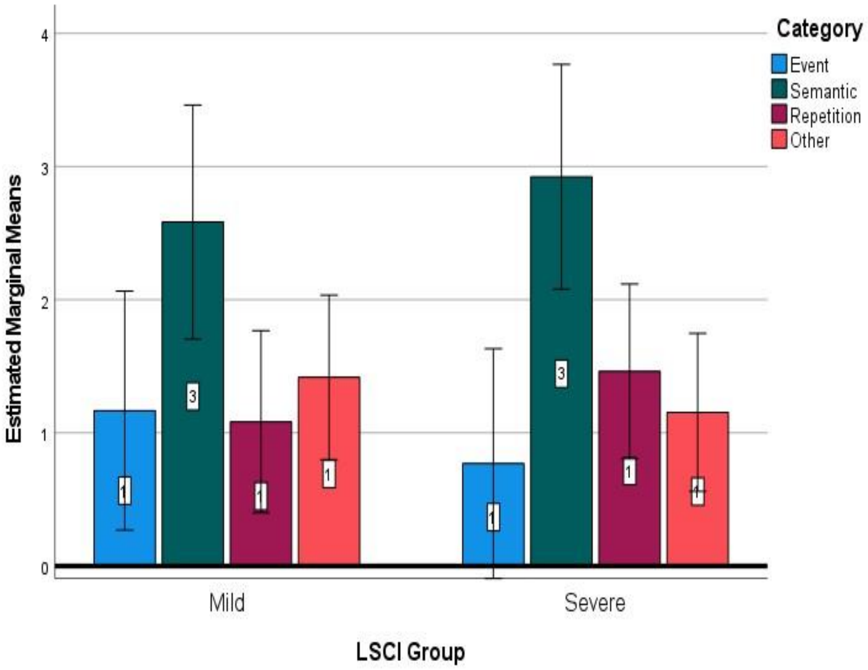
A further mixed ANOVA assessed whether the internal detail categories (event, time, place, perceptual and emotion) varied with LC severity (Mild vs Severe). There was a significant main effect of category (*F* (2.65, 23) = 10.54, *p* < .001, *ηp²* = .314) as illustrated in Figure 40. Post hoc pairwise comparisons using the Bonferroni correction showed that event details were recalled significantly more than time (*p* = <.001), place (*p* =.002), and perception details (*p* =.010). Additionally, emotion details were recalled significantly more than time details (p=.008). However, the interaction between category and LC severity was not significant (*F* (2.65, 61.09) = 1.85, *p* = .153, *η²* = .075), suggesting that the total details recalled in each category did not differ based on LC severity. Both groups showed similar mean totals across categories.

Figure 40. Means of category recall for internal details LC severity groups.



The same mixed ANOVA design was conducted to assess whether the external details across categories (event, semantic, repetition and other) varied with LC severity (Mild vs Severe). Again, there was a significant main effect of category (*F* (2.07, 47.64) = 14.34, *p* < .001, *ηp²* = .384) as illustrated in Figure 41. Post hoc pairwise comparisons using the Bonferroni correction showed that semantic details were recalled significantly more often than event details (*p* = <.001), repetition details (*p*= <.001) and other details (*p* =.002). However, the interaction between category and LC severity was not significant (*F* (2.07, 47.64) = 0.90, *p* = .417, *ηp²* = .038) suggesting that the total external details recalled in each category did not differ based on LC severity.

Figure 41. Means of category recall for external details LC severity groups



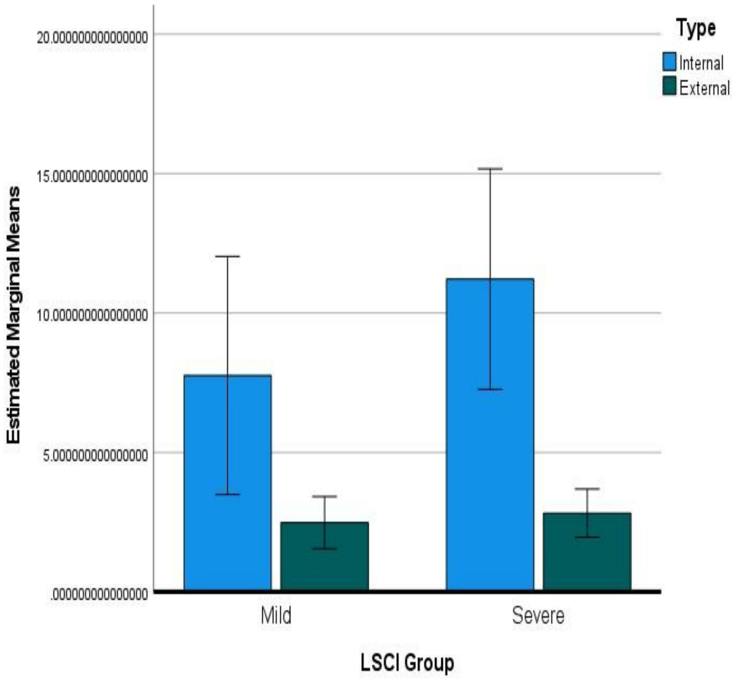
Future Event

The Adapted Autobiographical Interview technique and same scoring system was also used for the responses of the question ‘Can you picture a future event, like a dream holiday and describe it?’. All 26 participants provided prospective memory response. The word count ranged from a minimum of 40 words to a maximum of 935 words, (M = 209.30, SD = 175.39).

Firstly, a paired samples t test showed significant differences in proportion of internal and external total output, t (25) = 5.72, p = <.001, d = 6.19. PwLC produced significantly more internal details (M = 9.62, SD = 7.23, 95% CI [6.69, 12.54]) than external details (M = 2.66, SD = 1.54, 95% CI [2.04, 3.29]) which mirrored the findings of responses to the past life event question.

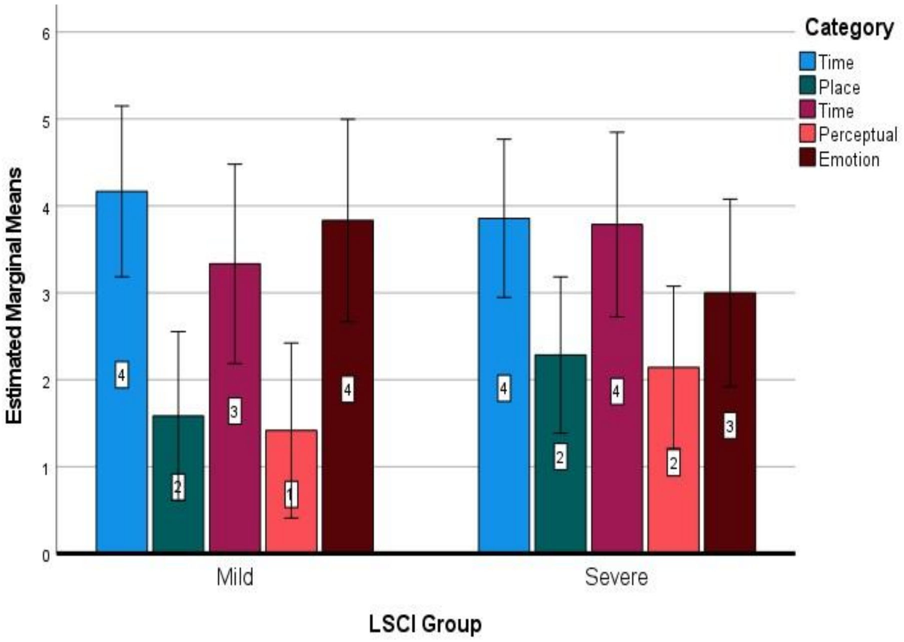
A mixed ANOVA assessing the possible interaction between LC severity (Mild vs Severe) and the type of information recalled (Internal vs External) found a significant main effect of recall type, (F (1.00, 24.00) = 32.29, p < .001, ηp^2 = .574), indicating that participants produced more internal details (M = 9.48, SD = 1.41, 95% CI [6.57, 12.39]) than external details (M = 2.65, SD = .308, 95% CI [2.02, 3.29], as shown in Figure 42. However, the interaction between recall type and LC severity was not significant (F (1.00, 24.00) = 1.68, p = .207, ηp^2 = .066.), suggesting that the total recall of internal and external details did not differ based on the severity of LC symptoms.

Figure 42. Mean ratio of internal and external total verbal output for both LC severity groups.



A further mixed ANOVA found a significant main effect of category (*F* (4, 21) = 11.79, *p* < .001, *ηp²* = .329) as illustrated in Figure 43. Post hoc pairwise comparisons using the Bonferroni correction showed that event details were recalled significantly more than time (*p* = < .001) and place (*p* = < .001). Time details were recalled less than place (*p* = .007) and perception details (*p* = .030). Place details were recalled more than perception (p = .004). There were no interactions between category and LC severity (*F* (4, 21) = 1.36, *p* = .252, *ηp²* = .054) suggesting that the total details recalled in each category did not differ based on LC severity. Both groups showed similar mean totals across categories.

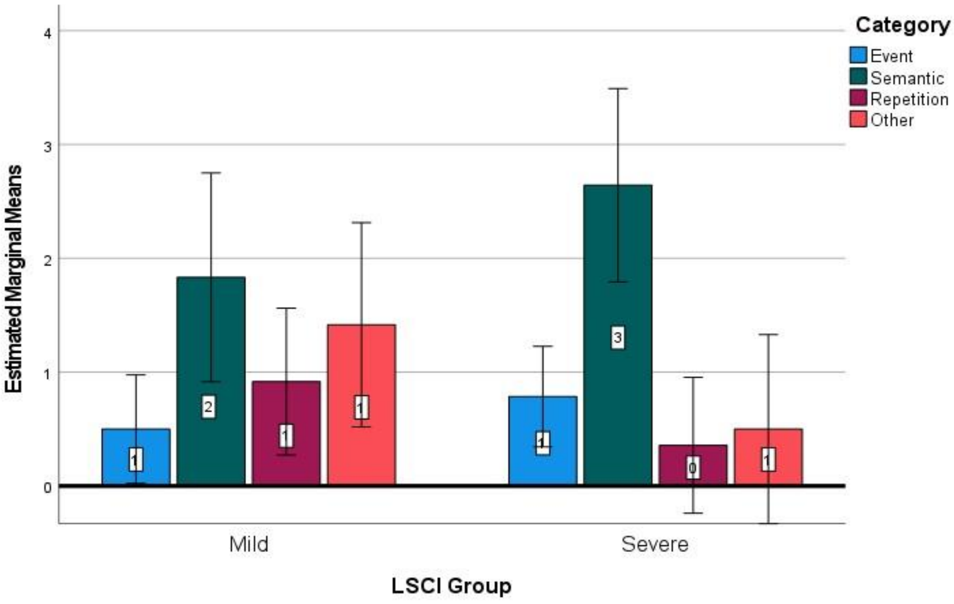
Figure 43. Means of category recall for internal details LC severity groups.



The same mixed ANOVA design was used to assess the external details across categories and found was a significant main effect of category (*F* (1.97, 47.23) = 10.37, *p* < .001, *ηp²*= .302) as illustrated in Figure 44. Post hoc pairwise comparisons using the Bonferroni correction showed that semantic details were recalled significantly more than event (p = < .001) and repetition details (*p* = < .001).

There were no the interactions between category and LC severity (*F* (1.97, 47.23) = 2.76, *p* = .074, *η²* = .103) suggesting that the total external details recalled in each category did not differ based on LC severity.

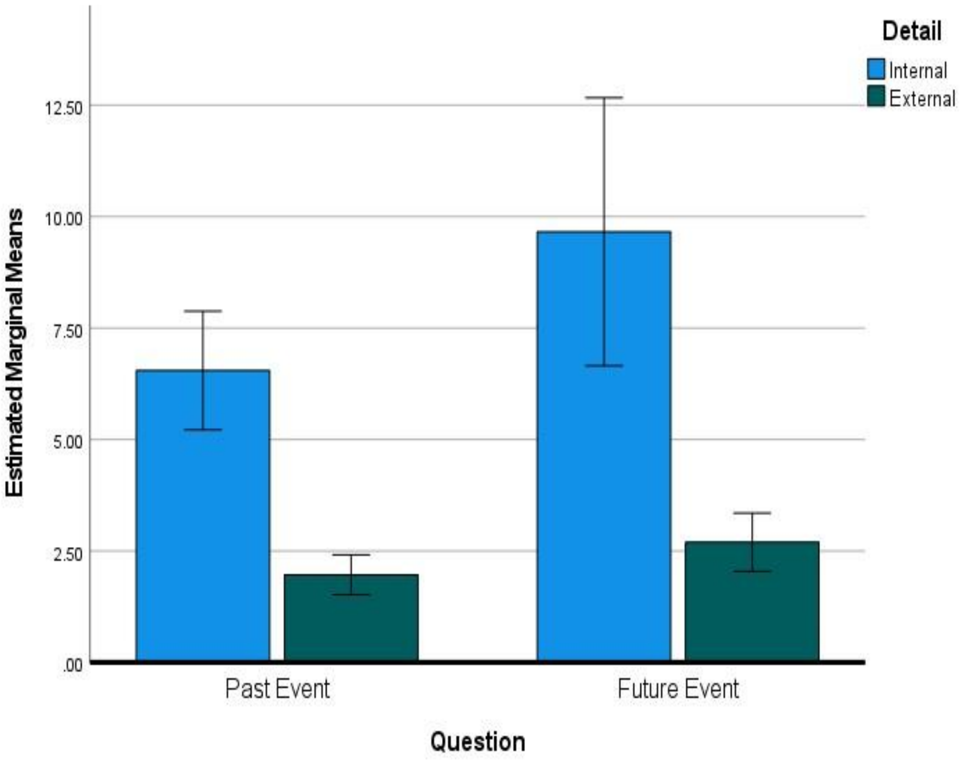
Figure 44. Means of category recall for external details LC severity groups.



A 2 (Question type: Past Event vs Future Holiday) × 2 (Detail type: internal vs external) x 2 (LC Severity: Mild vs Severe) repeated-measures ANOVA was conducted. There was a significant main effect of detail type (*F* (1.00, 23.00) = 70.85, *p* < .001, *ηp*² = .755), indicating that participants recalled significantly more internal details than external details across both questions, as shown in Figure 45. The main effect of question type did not meet the threshold for statistical significance (*F* (1.00, 23.00) = 3.96, *p* = .059, *ηp*² = .147). However, the large effect size suggests a mean difference in the overall amount of information recalled between the two questions.

Participants recalled more internal and external details for the future event than the past event (internal 9.74 vs 6.54; external 2.71 vs 1.97), suggesting that prospective memory may be more intact than retrospective memory. There were no interactions with LC severity for detail (*F(1.00, 23.00) = 1.61, p = .217, ηp² = .065*) or question type (*F*(1.00, 23.00) = 1.23, *p* = .279, ηp² = .051) and there was no significant interaction (*Question* × *Detail* × *LCSI group*), *F* (1.00, 23.00) = 1.75, *p* = .199, *ηp²* = .071, suggesting that LC severity does not affect internal or external details recalled across past and future events.

Figure 45. Means of internal and external recall for past and future events.



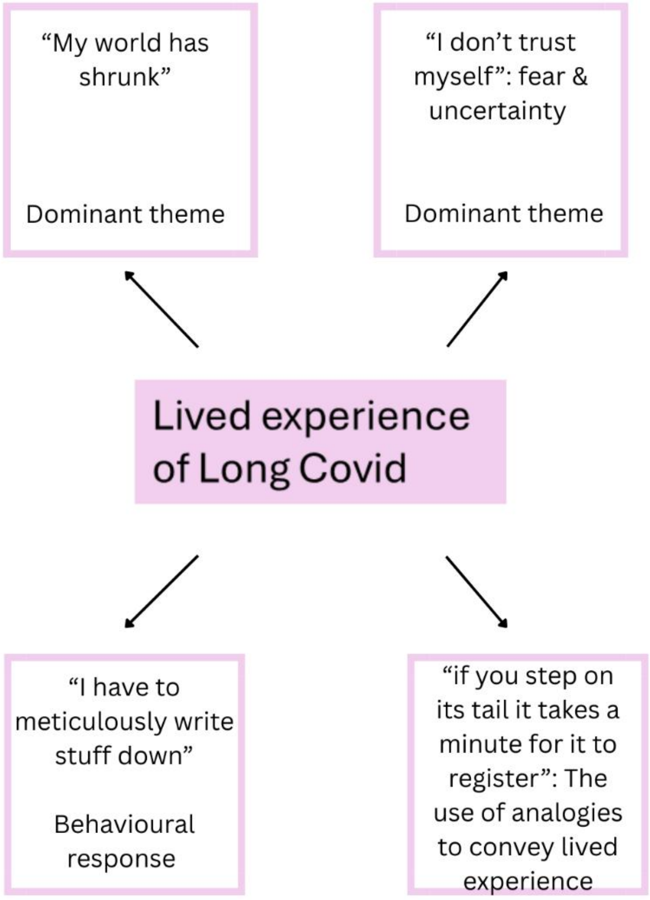
Summary of findings for the Adapted Autobiographical Interview results

The participants generated more internal than external details for both the past and future events, however there were no interactions between details and LC Severity. The mixed ANOVA was marginal for the main effect of question type. The results indicate that LC Severity does not significantly impact retrospective or prospective memory performance.

Themes

During the coding process several themes were generated. Braun & Clarke (2021) recommend using between two and six themes within a 10,000-word document to ensure richness through the analyses. Alongside delineating specific memory difficulties, the data collected led to the construction of four key themes. The themes displayed in Figure 46 will be discussed in turn.

Figure 46. Overview of themes from the semi-structured interview



Theme One: “My world had shrunk”

The memory difficulties described by participants had a varying impact on their everyday lives, affecting not only cognitive function but also other aspects of daily living, some of which have been previously discussed (Chapter Two Discussion). One participant reported examples of their daily memory lapses, *“I would do things like...I'd find, I don't know, pegs in the fridge or like lemons in the bloody toilet, or something like absolutely bizarre”* (pwLC10), while others described disorganisation within their home lives caused by their forgetfulness,

> “*and I'm always losing things, because I forget where I put things in our house. We're trying to sort our house out, which has kind of made it worse because things are moving where they used to be, and then I can't remember where things are*” and “*I lose everything. I have to be really strict with myself, of putting stuff down in the same place so that things have homes, my glasses, I’m forever losing my glasses and car keys, mobile” (pwLC22).*

Participants shared their need to adjust their activity levels to cope with cognitive fatigue “*one of the things that you end up doing is, of course, resting a lot*” (pwLC20) and *“It's preserving energy and just doing kind of the bare minimum”* (pwLC24). The description which is captured within this theme name, “*my world has shrunk to one room*” (pwLC4) was shared by others who could no longer engaged in their hobbies. One participant said

> *“Also things like everyday things like reading a book. I love reading a book. Now, I don't retain either the story or the detail as well as I used to. So, I will read a book, say it's a novel. I will read a novel and enjoy it, but probably like*

> *a few days after that I wouldn't be able to recall the finer details of the story. I find it difficult, say, to remember, like the villain's name, or some of the plot twists, or some of the sub characters, details. Whereas I never used to struggle with that sort of thing" (pwLC11).*

Another participant said how reading had also been a concern for them

> *"I am a big reader, and my eyes would just skip across page and I kind of struggled to get through the first sentence. All right, I've got that. Get to the next sentence….then that first sentence, I'd already forgotten what I'd read. So it was really just impossible…. And then, as I could read very slowly but not be able to remember what I'd read, it was like, what was the point in that exercise and so I didn't ever want to push it. I didn't want to like have sort of cognitive fatigue"*
> *(pwLC19).*

Another commented how activities of daily living have become too difficult *"cooking like I don't cook now….I just don't touch it now, because I just can't. I just can't manage it" (pwLC5).* These accounts highlight how simple hobbies are or have been out of reach for some people living with LC. Other restrictions to daily living due to memory impairments were raised regarding using technology,

> "*You know, I go to put the laptop on, and I'm like, how do I turn it on. How do we get onto outlook? How do I send a new email? How do I not know this?"*
> (pwLC15).

The participant elaborated on how this made them feel limited in their independence and impacted their sense of self,

> *"That drives me absolutely balmy, not being able to access information or just get on with the day or yeah sometimes I have to wait for my husband to come home…And then I say I know that I should know this and I don't know why I can't work this out, but I just can't like I just can't get this right*".

Another participant talked about the reality of LC upon their daily life by describing three ways in which memory had disrupted their routine tasks,

> "I *think it has been directly impacted and it's affecting quality of life about three ways, going to the shops and trying to remember where it's been parked or going to the shop to do um do shopping and if I have a list of what I need is in my head rather than on paper then I have real difficulty. And I regularly come back not having got what I wanted, but having got half a dozen other things. Secondly If I'm going from room to room, I might forget what I've gone to the other room for, and thirdly, if I think to myself, oh yeah, later on I must umm take my medication…. it's meant that I have often forgotten to take medication" (pwLC1).*

This account illustrates how memory difficulties present challenges for maintaining basic routines, which links to the episodic and procedural concerns highlighted in the specific memory challenges results.

Another everyday task that participants described as being affected by memory and cognitive difficulties was driving. More specifically, one participant shared how navigating familiar journeys was challenging

> *"…that's terrible now [driving]. I didn't get as confused as I do now, I really do struggle with that or trying to work out exactly what lane I need to be in or interpreting. Yeah, definitely driving is a big issue*" (pwLC3*).*

Another participant shared how difficulties with driving affected their independence,

> "*I've noticed that my driving is a lot more difficult…and that for me is a major problem. With my car is my freedom. Yeah, I live rurally, the public transport here is awful and if you don't have your own means of transport then you are significantly limited to what's available around you, that's one of the biggest things for me that I've really noticed" (pwLC21).*

Other participants described forgetting personal care,

> "*….have you brushed your teeth? And I was like no, I forgot to brush my teeth, but it's not something that other people have to specifically remember. I have to specifically remember everything*" (pwLC6) and "*there have been times when I've put like clean my teeth in my diary just for a while to help me remember because I might forget otherwise and then go out and think I haven't cleaned my teeth. Why have I not cleaned my teeth*" (pwLC15). One participant shared, "*if I can bathe and wash my hair it's a huge win*," (pwLC 24) highlighting how minimal daily tasks are achievements for some pwLC.

Reduction and limitations in daily activities including the ability to perform personal care is often evident in individuals with chronic illnesses (Nacul et al., 2021b), including those living with Parkinson's (Hariz & Forsgren, 2010) and Chronic obstructive pulmonary disease (COPD) patients (Bendixen et al., 2014). This theme highlights how the previous raised difficulties in procedural memory manifest in everyday life routines and activities.

Theme Two: "I don't trust myself": fear and uncertainty

This theme explores the sense of fear and uncertainty that was present among participants. Fear and anxiety, not only related to sense of self and abilities but some participants also described fear of the future. The use of the word "scared" was prevalent within many different contexts for pwLC and linked specifically to memory deficits. One participant described how they were concerned about forgetting appointments,

> *"The practical point of I mean, I'm just scared of missing appointments or being late. So, I think that's in because I've got so many things like this week. I've got something every single day. Which has caused me anxiety, anyway. But yeah, I'm just scared of getting places late or forgetting, and so that that sort of has an impact" (pwLC4).*

Others expressed concerns about forgetting important information,

> "*I get so scared, I'm gonna forget and sometimes, you know, maybe 50% of the time, I won't forget it"* (pwLC14) and "*If a bump into somebody, for*

> *example, and they start talking to me, I can start getting quite overwhelmed by it. That's to do with memory, maybe the fear of have I forgotten something?"*
> (pwLC24).

More concerningly, one participant expressed their experience of forgetting people and how their memory reduced their ability to recall vital information about people in their lives,

> "*like an anxiety oh, gosh! I've forgotten that person, like weeks have gone by, months have gone by, and even now I think did she die? Did she die, I've not seen that person? She must have died! like, when did she die? And I just can't remember, it sounds awful, I can't remember if someone died or not"*
> (pwLC15).

These concerns demonstrate how memory impairments are contributing to feelings of anxiety, reduced confidence, fear and shock at the inability to recall information from memory. Other participants described fears associated with safety, including getting lost,

> *"I got outside after months and I've lived in the same place for like 23 years, and it's literally I couldn't remember. It was really frightening. I couldn't remember where the like the pharmacist was like somewhere that I've been to for years and years and years and it was the first time I suddenly realised that I had a problem"* (pwLC10) *and* "*driving my car home from the garage that I've*

> *been using for well, they've been where they are for like 15 years, journey I've made many, many times and driving my car home, and I know literally that two towns really close together and getting lost. I have no idea where I was, that's happened a kind of a few times when I'm driving places"* (pwLC13).

While others discussed the fear of unintentionally hurting themselves, which again in independence limiting,

> *"….I definitely am but I'm still a liability. I've almost stabbed myself multiple times, including what the most common one is dropping a knife which had gone a few times. I've had a few close shaves. I thought it probably would have gone through my foot"* (pwLC5) and "*I am absolutely terrified because I've done it once where I've gone to open and get something out the oven with my bare hand and I'm absolutely terrified of doing that now"* (pwLC20).

The account from a participant, compares their everyday memory to "*scrambled egg,"* and includes their thought processes with regards to safety, "*I can't fathom like whether I locked the front door or not... I'm sat here talking to you, having a conversation and I'm fretting that I've forgotten to lock the door again*" (pwLC21).

Associated with fear and safety concerns was the narrative that some participants portrayed a sense of self doubt. The term "I don't trust myself" was used by five participants during their interviews in the context of different aspects of their lives, highlighting how the perceived loss of cognitive ability is directly impacting participants sense of self. This fear and lack of self-confidence, described by one participant as "*battered*" (pwLC20), have contributed to individuals referring to themselves as a "*liability*" (pwL5), having concerns of "*people thinking I am an idiot*" (pwLC4) and "*it [memory] makes me feel like a really unreliable person*" (pwLC6). The statement "*if I was a normal person*" (pwLC6) illustrates an identity shift and reduced sense of self. This has been seen in research into other chronic illnesses, where persistent symptoms and symptom impact, alters a person's sense of self and increases internalised stigma (Van Bulck et al, 2019). In addition, internalised stigma has been previously documented in LC literature (Callen et al, 2022; Samper-Pardo et al, 2023; Schiavi et al, 2022) as well as within other chronic illnesses (Quinn & Earnshaw, 2011).

Alongside these fears, many participants expressed concerns and uncertainty about the future. One participant reflected on concerns of permanent damage and the longevity of LC sequalae.

> "*I thought initially that maybe after Covid that it might be a short period of the memory being fuzzy. But it does seem to be a longer-term issue now. almost as if damage was done that was permanent rather than transitory. I like to liken it to, if you think of the fact that there's a TIA, a transient ischemic attack. Where you suffer the same symptoms or effects as a full stroke. But with the stroke, those effects are long-term and ongoing and need physiotherapy and everything. Whereas with the TIA, it's kind of out the way and disappears quite rapidly and you promptly revert to normal. I think Covid has had the sort of stroke-like effect of making a longer-term impact on health. Rather than just something that was there for a month or so and then went it's no longer then,*

> *seems unfortunate to be lingering which is what I had hoped wasn't the case initially"* (pwLC1).

Similarly, other participants mentioned uncertainty of permanent damage,

> "*It does worry me that it's like this [memory] and I don't know if it's got the potential to heal at this point due to inflammation of the brain*" (pwLC4) and *"…seeing them really struggle with their brain [parents with dementia], I did think the other day, and I thought, Oh, my God! Like what if my memory does not return to. you know. Is this actual damage in the brain? Is this blood supply?"* (pwLC19).

For others uncertainty regarding treatment and access to services and how that could affect their future was shared, evidencing the feelings of uncertainty of what the future holds in store for pwLC.

> "…*I mean, if I recover. But I'm never going to recover unless we get antivirals"* (pwLC5), "*I applied for the Nuffield health long Covid program. They turn me down. Oh, no, I'm too sick to participate unbelievable"* (pwLC4) and "*At the moment within the long Covid recovery, it's quite scary with all the long Covid clinics getting closed as well. What's the support going to look like moving forward?"* (pwLC22)

Trajectories of memory impairments and how they may manifest over time were raised by some participants. For some participants progress was limited, one participant reported that things had become "*worse in the last 12 months*," (pwLC1) and another stated, "*I have really deteriorated*" (pwLC2) and "*even at my best, my brain is still completely lost*" (pwLC10) while for others there were indications of partial improvements, "*I'm much better than I was two years ago but I'm still not there [recovered]"* (pwLC25) and "*more better days now than before although it still varies*" (pwLC 14) and commenting "*I'm less tired which basically means everything's a little better*" (pwLC 20). The nonlinear rates of recovery which appear to vary between individuals may contribute to uncertainty of what the future holds.

The quotes demonstrated that pwLC were clearly fearful of different types of their memory and how these impact their daily lives. Everything from STM, to episodic, semantic (forgetting people and whether they died) and their spatial memory. Fear is a prospective emotion (Stanley, 1894) in that you're afraid of something that hasn't happened yet, and therefore the uncertainty and the fear that goes with it pwLC experience could be an indicator of an impairment in prospective future memory.

In the previous thematic analyses (Chapter 2), participants expressed a multitude of emotions including depression, alongside the fear and anxiety raised here, which may suggest that health anxiety and psychological support must be considered for pwLC. One participant from the United Kingdom observed these resources are currently lacking within the NHS

> "*no one at any point like the long covid clinics or GPs… talked about, oh you've lost xyz and lost your job, do you need anything? Can we help?... the mental health and cognition are a real gaping level."* (pwLC22).

Research has shown that individuals who are chronically ill are at risk of psychological distress (Verhaak et al., 2005). There are high levels of prevalence of psychological disorders, such as depression in different populations of chronically ill patients including those with arthritis (Creed, 1990) and individuals living with diabetes (Anderson et al., 2001), this should be a consideration for pwLC. Mental health concerns have been raised previously by pwLC (Burton et al, 2022) and in previous epidemics such as severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) (Rogers et al., 2020).

Theme Three: "I have to meticulously write stuff down"

To help compensate for memory difficulties, the participants shared various techniques they used to support their functioning. Seven participants explained how routines were key to their ability to function with LC,

> "*Everything is quite considered and structured. I couldn't do too many things in my day, because I'd fail at doing one of them at least"* (pwLC6) and "*being aware and knowing exactly what routine, I just find having a routine just really helps"* (pwLC24).

Participants being aware of the need for such structure echoes the self-management and acceptance pwLC discussed in the previous thematic analyses (Chapter Three). The participant went on to say,

> *"it's the NHS that introduced that to help me with not just me, but people with long Covid and long Covid clinics… The three P's. Plan, pace, prioritize. I've stuck by that till this day. I check in with myself in the morning. Right? How*

> *you, feeling right, Plan, Pace, Prioritize your day"* highlighting that this has been a helpful, impactful strategy.

Participants reported the use of different memory aids to navigate their everyday lives. Calendars were used by just under half of the participants, while others used daily planners and to-do lists to organise themselves and to use as a prompt throughout the day. For some participants visual cues were also used to assist with their memory including looking at photos in an attempt to trigger recall (*N* = 3) or journalling to refer to (*N* = 2). Over half of the participants shared that "writing everything down" was a strategy to ensure things were remembered and tasks were completed. Some participants discussed how they wrote questions down ahead of appointments and others shared how they kept a written record of their medical history,

> *"I do write everything down after the event. I have this book, which I'm as you can see...But yeah, I've got everything written down. But I also have everything in my phone, so that if my other half ever needs like clinical notes, because I'm incapable"* (pwLC20).

Technology was a useful tool for some participants to provide prompts and remind them throughout their day. Participants reported using alarms, messaging and audio recordings. One participant shared how technology was promoted to support with activities of daily living such as medication compliance, but they acknowledged they did not want to be dependent on such strategies,

> "*I did explain to the NHS I was sometimes forgetting to take my medication and stuff like that. So, they got me an Alexa unit to remind me, which is Okay, quite handy. But obviously, I don't want to rely entirely on tools to help me with my memory. I would rather my memory just be good you could remember"* (pwLC1). Another participant referred to the use of artificial intelligence (AI) for support, "*I have used chat GPT a lot of the volunteering stuff and started using cheats so like things like, if I wanted to write something I would do an audio like I've got a recorder now on my phone, so I'll just spew all my thoughts out and then it's got a transcribe, and I'll just copy and paste it, and then ChatGPT. I'll be like structure this"* (pwLC5) in an attempt to manage cognitive burden.

Finch, an application, was used by another participant to help support their memory,

> "*And a friend introduced me to an app called Finch, which kind of gamifies it. I guess you get like a little bird, and then you can earn little points when you tick off tasks" (*pwLC8).

The benefit of social support as a strategy to prompt was highlighted by some participants,

> "*you know my partner does a lot to like just to get me through a day to like kind of, you know. Be like you're doing this, this is what you need to do, have you eaten? that kind of stuff"* (pwLC6) and "*I was chatting to my husband, and I was like, Can I just double check? I've recalled the day when this all happened…"* (pwLC24).

Another reported how the act of telling someone helped to self-prompt,

> "*if I tell somebody I need to remember something, I remember it. Yeah, so I tell the other half, I'll say Oh remind me tomorrow I've got to do so and so, and it'll be like I remember, but I won't necessarily always remember at the right time"* (pwLC20).

Interestingly, some participants reported how association and visual cues prompted them,

> *"I've done a few little things I learned on my long covid sort of training that we did support groups like they do, I think they might call it twinning where they say like, if you forget to take your tablets every day, put them with your toothbrush, because remember to clean you, you probably do clean your teeth every day…. So I've done a bit of that, and just been a bit more proactive about things like, if I need to remember to do this every day, then maybe I'll just leave it out on the side, so that I see it and a bit more sort of deliberate routine"* (pwLC15) and "*for instance, when I take my medication, it has to be, it's not just about having it in a dosage box. I have to now have it in front of me. It's like things just completely go"* (pwLC10).

Another participant shared that they developed a strategy to ensure they were compliant with their inhaler, *"I take an asthma inhaler in the morning and it has to be two puffs, and I have to look before I take the inhaler….I'm building up strategies to cope with forgetting things right as I do them….yeah, I try to find coping mechanisms and so far, it's worked"* (pwLC17).

Additionally, for others learning to adapt has been helpful and some participants referred to other coping strategies that helped them manage their illness. One participant suggested that inspiration and comparison with others was a coping strategy, “*If those people could get through that [discussing 9/11 terrorist attacks], I can get through this”* (pwLC5). Another participant reflected how they were continuing learning about their illness from the use of different strategies and how to cope with the implications of it, *“I don’t think it is because my brain has recovered, it’s more I’m learning how to manage”* (pwLC10), and another commented how their self-awareness helped them to strategize, *“I can now recognise it as a warning sign” (pwLC15).* Others used their refusal to give up on their personal goals despite their ill health as a form of coping and motivation *“I was just like I've got goals to achieve. I'm not letting this take my goals away like doing the PhD, I was so close to”* (pwLC24) and “*I just thought, of course, I'm going to recover. Humans have amazing ways of regenerating, yeah, caring for themselves. And I thought of course, I'm gonna get better”* (pwLC19). The sentiment of the last reflection highlights the personal resilience that pwLC demonstrate which was also evident in the last chapter.

Strategies that pwLC report using for assisting with impaired memory have been used in others with memory difficulties including dementia (Dröes et al., 2011) and ME/CFS (Sebaiti et al., 2022).

Theme Four: "If you step on its tail it takes a minute for it to register": The use of analogies to convey lived experience

> "*In fact, metaphors may be as necessary to illness as they are to literature, as comforting to the patient as his own bathrobe and slippers. At the very least, they are a relief from medical terminology*" (Broyard, 1992, p. 18).

Among the rich data collected during the interviews, an interesting commonality was the way in which some pwLC used analogies and metaphors to portray their experiences. When discussing information processing, one participant used the following analogy to describe their experience, summarising a delay in ability to process new information.

> "*Like a dinosaur and like before, instead of it was like if you stood a cat's tail when the cat would yelp, whereas now it's like a brontosaur or an apatosaurus, if you're an apatosaur, if you step on its tail it takes a minute for it to register. I always think it's a little bit like although it has improved with me, it's still not great*" (pwLC5),

Although the participant referred that this issue had improved, it remained challenging. Another participant used a comparison to portray the slowed retrieval of personal episodic memory to rusty equipment to help communicate the efforts and reduced abilities to access memories,

> "*Sometimes it takes a bit of a reminder... and then I could feel the hamster turning in the wheel... but it's definitely like the wheel is rusty"* (pwLC21),

While another likened their experience of memory to impaired technology,

> *"It's almost like I have a whole bunch of bad sectors in my brain and go back to the hard drive. So, until I create a new file so whatever was on that that sector before is corrupt"* (pwLC20) highlighting how the process of recall feels unreliable.

When referring STM, it was described as *"almost like a brain worm—it gets stuck in there and I can't remember,"* (pwLC14) and *"it's like the pathway was cut,"* (pwLC17), a further illustration that accessing recent memory is difficult. Whereas long term memory retrieval was described as *"it's like it's just not there properly. It's like a fake. It's almost like it hasn't been imprinted in properly"* (pwLC13) and *"it does feel like I've almost, yeah, had to sort of dig… dig out a new pathway to get to those things"* (pwLC15), indicating further evidencing that the retrieval process of long-term memory can be challenging.

The use of analogies shows insights into how some pwLC articulate their lived experience and is not an uncommon finding in health-related qualitative research with chronic pain (Coakley & Schechter, 2013) and women with endometriosis (Bullo, 2021) for example. Analogies enable patients to communicate their lived experiences

(Lakoff & Johnson, 2020) and are typically used to enhance understanding alongside using visual descriptions and abstract comparisons.

Chapter Discussion

This chapter aimed to capture how memory difficulties manifest in everyday life and are problematic for pwLC through a lived experience perspective. The results have provided some interesting findings into the lived experiences of pwLC as they relate to Atkinson and Shiffrin's (1968) multi-store model of memory, which may aid understanding of the sequalae of LC. Alongside the specific memory difficulties that pwLC disclosed, four themes were generated from the thematic analyses of participants' accounts.

The participants who took part in this study had been living with LC for just under 40 months and had an average of 11 long lasting symptoms, which are comparable to the pwLC who took part in the other studies. Participants had high levels of fatigue and low perceived quality of life. Most participants' limitations corresponded to the response option 'I suffer from limitations in my everyday life as I occasionally need to avoid or reduce usual duties/ activities or need to spread this over time due to symptoms, pain, depression or anxiety. I am, however, able to perform all activities without any assistance'. These reductions were evident in their disclosures throughout the interviews.

From the data it was apparent that STM is problematic for many pwLC, with 69% of the sample of this study confirming issues with their STM. For those affected, and based on the accounts shared, it appears that both attention and rehearsal processes, alongside accessing STM, may be impaired in LC. LTM initially appeared not as affected as STM, however, several participants reported that this felt more difficult to access. Over half of participants were able to recall immediately what they had for dinner a few days previously, while others responded that they doubted their ability to recall or were not sure. Memory of foods and mealtimes have been shown to decline after the period, i.e. when the meal has finished (Armstrong et al., 2000; Fries et al., 1995) but there have been suggestions to link to encoding (Higgs, 2008), in which some participants seem to do in their recall by linking their meal with other cues. The encoding of multiple items with events has been previously attributed to the role of the hippocampus (Higgs, 2008). Furthermore, there is evidence to suggest that social interactions while eating enhance experiences compared to eating alone and people generally eat better in the presence of other people (De Castro, 1995), which may explain why those who referred to remembering better when other people were involved. The literature suggests that for recall of eating patterns, particularly certain meals, individuals use multiple memory and learning processes including sensory, somatic and contextual memory (Higgs, 2008). Furthermore, the consumption of food and the ability to recall a single occasion such as a mealtime is influenced by various cognitive processes including attention (Bellisle & Dalix, 2001), which has been documented as problematic for pwLC within this thesis. Research into the eating behaviours of patients with amnesia due to hippocampus damage has suggested that the hippocampus, as well as being critical for memory and learning, is also involved in the control of food intake. The famous patient H.M reportedly would eat a second meal immediately following a meal (Hebben et al., 1985), a behaviour that was also reported in other patients with amnesia (Diamond & Rozin, 1984). This may suggest that patients with amnesia have impaired ability to recall their recent eating due to hippocampal damage and thus engage in further eating behaviours. However, these studies focused on eating behaviours and appetites rather than direct recall of what was eaten, which was the focus of the present study. Nevertheless, our findings are compatible with the idea that the inability of some pwLC to recall a recent meal may be due to hippocampal deficits.

Interview questions about procedural, semantic, episodic and spatial memory, offered further insights into impairments in pwLC. Participants reported how procedural memory and the ability to link information was difficult. Semantic memory appeared impaired for some participants, who reported episodes of forgetting facts, word finding difficulties and difficulties recalling names. Sixty-five percent of participants reported difficulties around word finding and gave varying descriptions of how this impacts their daily lives. Semantic problems and verbal fluency have been previously reported as difficult for pwLC (Nersesjan et al., 2022; Wahlgren et al., 2022).

There were some reports that spatial memory is problematic with reports of disorientation, getting lost and banging into things. Object location memory (OLM) supports spatial information and the ability to make associations between self and spatial locations (Chan et al., 2014). When OLM was explored in pwLC using virtual reality LC patients performed worse than controls (Llana et al., 2024). Our finding support this with qualitative evidence to suggest that spatial memory in some pwLC is impaired.

As discussed in the introductory chapter, the MSM (Atkinson & Shiffrin, 1968) explains that attention and rehearsal are pivotal for memory retrieval, which may be impaired in some pwLC. Many participants confirmed that retrieval of information is difficult and gave examples of how this impacts their daily lives. The model suggests that the sensory store acquires information from the environment to enable storage of information however, this process does require attention. Some participants confirmed that attention is problematic, thus information rehearsal may be prevented to transfer information, which in turn may affect retrieval abilities in LTM.

The levels of processing model (Craik & Lockhart, 1972) may offer some explanation to the memory difficulties, and the strategies used to overcome them, that were reported by pwLC. While we found evidence in the accounts of pwLC to suggest that deeper processing behaviours occurred, its cognitive burden for some pwLC mean that shallow processing was more commonly used and thus LTM recall was affected. The participants that discussed strategies to link information together confirmed this did help with recall which is a tool that might be helpful to encourage deeper processing in pwLC.

The working memory model (Baddeley & Hitch, 1974) model may also offer explanations for the results. Specific tasks that may be attributed to certain components of the WMM, may be affected in some pwLC, based upon their reflections on how their memory difficulties affect their daily lives. The ability to problem solves, switch attention and multitask which is thought to be attributed to the central executive system, was reported by some participants. The ability to hold onto audio information to enable rehearsal, which is attributed to the phonological loop, appears to be impaired in some pwLC. This manifested as frequent forgetting and inability to engage in reading within their inner voice as they once had. Some participants reported difficulties with spatial navigation including the ability to drive, which may indicate concern with the ability to use their visuospatial sketchpad for spatial information processing. The difficulties in recalling conversations and other cognitive tasks may be attributed to deficits within the episodic buffer for some pwLC. Working memory is critical for performance of many cognitive tasks and it enables execution of complex cognitive tasks (Broadway & Engle, 2011). Learning new tasks, reading comprehension, communication and following instructions, all of which some pwLC find problematic, may be directly linked to WM abilities. Furthermore, the strategies pwLC reported using to support their memory, suggest they attempt to externalise the cognitive load of everyday living tasks through technology and visual prompts as examples, which may help to reduce cognitive burden and therefore enhance WM. Additionally, the use of rigid routines that some participants reported as helpful, may support automatic processes to enable the WM to be available for other cognitive tasks.

There is also evidence to suggest that working memory capacity in some pwLC is impaired which has been previously reported (Asghar et al., 2025; Mazza et al., 2021). Working memory impairments are reported to be prevalent immediately after a Covid-19 infection (Becker et al., 2025) but can also be persistent over time (Mazza et al., 2021). It has been suggested that when working memory abilities decrease so does the ability to perform daily tasks (D'Esposito & Postle, 2015), which may also help to explain the difficulties pwLC have with their day to day lives. Impairments of working memory have been linked to abnormal functioning the prefrontal cortex (Peltz et al., 2011), suggesting that in addition to hippocampal dysfunction, pwLC may have reduced prefrontal functioning.

Although the accounts within this chapter only constitute indirect evidence for impairments within the different models of memories, they do suggest disruptions in multiple stages of memory processing. Many pwLC described difficulties with concentration and initial information intake, supporting the possibility that there are impairments in encoding. This, alongside fatigue, which can hinder attention may account for some of the difficulties described. The accounts of concerns with multitasking, mental manipulation and maintaining information over short periods of time, may align with deficits described in Baddeley and Hitch’s model of working memory (1974), particularly the central executive. Despite participants remembering LTM, many acknowledged the difficulty of accessing information which may suggest impairments in retrieval processes. This could potentially be attributed to weakened encoding or inefficient consolidation. These findings not only can be related to memory models but also highlight the need for support for fluctuating memory difficulties for pwLC.

Participants were asked to recall a past significant life event and to describe a future holiday. Both responses provided internal and external recall details that were scored and quantitatively analysed using the adapted autobiographical interview technique (Levine et al., 2002). Participants recalled more internal details than external details for both the past and future questions. This finding aligns with existing research that suggests internal details of an episodic and content specific (internal) nature are more often recalled than external details relying on semantic information (external) (Levine et al., 2002). Interestingly, for future events participants generated more details for both internal and external components compared to past events. This contrasts with patients with amnesia who often demonstrate impairments both in recollection of their past and in future imagination (Hassabis et al., 2007; Squire et al., 2010). Schacter & Addis (2007) suggest that memories of the past help shape expectations of the future, thus as pwLC were able to recall some episodic memories in detail, this may have supported their ability to imagine a future holiday. This intact ability of future imagination suggests that pwLC have retained the capacity to mentally time-travel (Suddendorf & Corballis, 1997). Additionally, this could reflect a preference for pwLC to think more about the future than the past. This could also link with their fears disclosed, which is a prospective emotion. Research has shown that people tend to generally think more positively about the future than the past, as the future is perceived with greater control (Grysman et al., 2014). This may be especially relevant for pwLC for whom reflecting on pre-LC experiences, are tainted with uncertainty and may induce a sense of loss, a theme echoed in the qualitative analyses presented in Chapter Three. For both questions, there was no effect of LC severity on the number of internal/external details nor category total scores, which may suggest severity does not impact episodic or semantic recall for this group of pwLC, within the context of these questions.

The themes discussed within the results capture the everyday challenges that pwLC face. The first theme provides context on the everyday realities for pwLC living with memory difficulties. It demonstrates how memory difficulties disrupt routine aspects of daily life from personal care, being able to engage in hobbies and confident driving, all of which limit independence and impact the sense of self. Difficulties with performing activities of daily living have been widely reported by pwLC (Schmachtenberg et al., 2023b). The definition of chronic illness includes ‘the limit of activities of daily living’ such as personal care and eating (Goodman et al., 2013) as well as tasks such as cleaning, shopping and cooking (Avlund, 2004), which have been evident within this theme. These limitations, alongside often balancing the demand of the illness itself, can affect an individual’s ability to manage daily tasks (van Houtum et al., 2015).

The second theme highlights how internal fear as well as uncertainty about the future, adds further complexity to pwLC that should be carefully considered. Fear as a result of being chronically unwell is often referred to as health anxiety (Janzen Claude et al., 2013) . Health anxiety (HA) can often include negative emotions, including fear and danger perception (Taylor & Asmundson, 2004) which were evident in this theme. HA may be considered a response to managing a chronic illness (LeBouthillier et al., 2015), where there is uncertainty around health and wellbeing (Lebel et al., 2020), which has also been identified in previous LC qualitative research (Burton et al., 2022; Ireson et al., 2022; Kingstone et al., 2020).

The reduced sense of self and internalised stigma captured within these interviews, was also evident in the previous chapter, which suggests this may be an issue for pwLC. Illness identity, which is defined as the degree in which a chronic condition is integrated into someone's identity (Oris et al., 2016), not only captures how someone views their illness and treatment, but also how they consider themselves and how their illness integrates into their sense of self (Van Bulck et al., 2019). There is evidence of each of the illness identity model constructs both within this study and in the previous thematic analysis in Chapter Two. Participants described feelings which could be translated as engulfed by their LC, particularly in relation to the impact on their everyday lives. Furthermore, the often fluctuating and debilitating symptoms and increased need for medical care, which were previously highlighted could leave pwLC feeling like their illness is dominating their identities due to the restrictions they have discussed. A reduced self-worth and sense of self have been evident for some participants, including referring to their 'old' self and describing feelings of embarrassment at their limitations. which may indicate the rejection construct.

Within both the last chapter and in the current study, there were some indications to suggest elements of acceptance for some participants. Participants have shared reflections which demonstrate resilience and adaptation. While there were fewer direct links to enrichment within the data sets, this may have been due to the limitations of LC that were found to be persistent and which may reduce abilities to adapt functioning. Identity and physical functioning have been shown to be related in previous chronic illnesses literature (Leventhal et al., 1999). There is also research to suggest that acceptance is usually related to fewer symptoms of an illness (Evers et al., 2001). Within this sample, pwLC were living with 11 symptoms after 40 months on average, which may explain why only some participants showed acceptance. Furthermore, those with increased number of LC symptoms had reduced quality of life meaning that acceptance may be harder. The nonlinear recovery of LC, coupled with the fluctuating symptoms, may have contributed to why fewer participants demonstrating the enrichment construct.

The third theme captured the use of a mixture of different strategies and techniques, pwLC find helpful to support and prompt memory difficulties. Social support and learning to adapt were useful to some participants. A refusal to give up on their recovery journey by some participants, mirrors the resilience seen in the previous chapter. The behaviours and coping strategies of people living with chronic illnesses differ, depending on the illness itself, alongside personal and external factors such as support. Research has shown that those with greater acceptance of their illness show better adaption and reportedly reduced discomfort and confirm acceptance does not mean defeat but instead can help patients with self-confidence and feeling in control (Kowalska et al., 2019). Research exploring illness acceptance, found that acceptance of illness improved after a rehabilitation intervention, demonstrating the relationship between greater acceptance and functional status (Mazurek & Lurbiecki, 2014). Previous research has suggested that providing the tools for patients of chronic illness to cope and adapt to their illness, is effective for managing both physical and psychosocial sequelae. Acceptance has been explored in a variety of chronic illnesses including diabetes (Bąk et al., 2017), dialysis patients (Kurowska & Kasprzyk, 2013) and those with COPD (Uchmanowicz et al., 2016).

The final theme discussed the use of analogies to convey lived experience, which is not unusual within health-related research. The use of analogies and metaphors not only articulates lived experiences but also reveals some deeper insights into what it is like to be unwell (Gibbs Jr., 2020). They can help to create a vivid image of complex physical sensations (Kirmayer, 2008) and are used by patients regularly, for example by cancer patients (Gibbs Jr. & Franks, 2002), patients with pain (Semino, 2010) and those with anorexia nervosa (Enckell, 2002). Metaphors, both of positive and negative connotations, have been used to describe Covid-19 experiences (Palese et al., 2022). Patients with ME / CFS, the symptomology of which overlaps with LC, have also used metaphors to describe their lived experiences and multitude of debilitating symptoms (Devendorf et al., 2018). In a recent book 'I haven't been entirely honest with you' (Hart, 2024), where the author shares her journey of battling chronic fatigue after being diagnosed with Lyme disease, the use of metaphors and language are mentioned. Hart (2024) describes how she has used analogies and metaphors such as "*it's like wading through treacle*" and "*it's such a battle*" to try to begin to express her symptoms (p. 176). Interestingly she goes onto describe as a patient how she feels that words have negatively affected her physiologically and how she has needed to replace words in her vocabulary to reduce this. Research has shown that the language used affects emotions, whether it is single words (Scott et al., 2009) or sentences (Bayer et al., 2010) which was also evident within some of the accounts pwLC provided.

This study provides insights into how memory difficulties are experienced by pwLC in their everyday lives, however there are some limitations to acknowledge. The narratives presented were captured in semi- structured interviews and thus are self-reported by the participants, therefore these results do not provide direct evidence of underlying cognitive mechanisms for pwLC. Exploring the participants' narratives within established memory models gave context to their struggles. However, this data does not propose to directly confirm impairments in specific memory systems, but instead provides a picture of the daily struggles for pwLC situated within these models and how these difficulties manifest in everyday life.

The autobiographical interview task provided an insight into episodic and semantic memory for pwLC, but these responses may have been influenced by ongoing LC symptomology. This includes fatigue, thus they may not present episodic and semantic memory robustly. Furthermore, although the ratio-based scoring was used throughout for the variation in total output, the coding of internal and external details was not validated for reliability. Future studies should ensure dual coding to ensure reliable results. The findings from this study demonstrate a need for integrated programmes for pwLC to support cognitive impairments and the emotional and social consequences of living with LC. Clinical interventions should support cognitive compensation and management strategies to not only help to reduce burden but promote independence. Support groups for pwLC, in different formats to accommodate for fluctuating needs, may help to reduce isolation, uncertainty and internalised stigma as discussed in Chapter Four with the conceptual model of LC.

To conclude, the findings from this study help our understanding of which areas of memory may be impacted in those with LC and what support might be needed for pwLC.. Furthermore, due to the similarities between LC and other chronic illnesses as described within this thesis, advances in LC research, could aid understanding of other poorly documented chronic illnesses.

Chapter Five : Study Protocol

This manuscript has been submitted via Peer Community In process, with the hope for publication the Cortex journal. Due to time constraints of pre-registering this study and manuscript revisions, data collection and analysis have not been completed in time to be included in this thesis. However, as the study was planned, it was considered important to include this protocol within the thesis to demonstrate the planned progression of data collection.

Introduction

Long Covid (LC), also known as post- acute sequelae of SARS-CoV-2 (PASC) and post Covid-19 condition (PCC) are terms used to describe the multitude of symptoms that linger and continue after an acute Covid-19 infection has passed, preventing an individual returning to their pre-Covid health (NHS, 2023). SARS-CoV-2 causes widespread damage within the body and is reported to be impacting cognitive functioning, presenting as Long Covid (Hampshire et al., 2024; Miners et al., 2020). Inflammation in the hippocampus can result in long-lasting memory problems (Chesnokova et al., 2016) that are both objectively measurable and overtly expressed by patients with Long-Covid (LC) (Hampshire et al., 2024; Nouraeinejad, 2023a).

A commonly reported symptom in people with LC (pwLC) is ‘brain fog’, a nonmedical term that is used to refer to general cognitive dysfunction (involving word finding difficulties, memory impairments and dizziness amongst other symptoms) and has been linked to increased psychological difficulties in patients (Jennings et al., 2022). Severity of lingering symptoms, the length of time since the acute infections and the need for hospitalisation during the acute infection have been suggestively linked to poorer performance in cognitive tasks (Guo et al., 2022; Hampshire et al., 2024; Jennings et al., 2022). Cognitive deficits in pwLC have been delineated with cognitive assessment batteries such as the Montreal Cognitive Assessment (MoCA) and Cognitron. These have found varying levels of impairment in LC patients and concluded that the domains predominately affected are executive functioning, memory (both immediate and delayed), and processing speed (Del Brutto et al., 2021; Gautam et al., 2022; Hampshire et al., 2024; Ortelli et al., 2021; Rass et al., 2021). Impairments in mental and cognitive functioning have been associated with self-reported symptoms of poor memory or brain fog (Hampshire et al., 2024) and may be related to neuropsychological alterations in pwLC (Ortelli et al., 2021b). Although those aged between 45 and 54 years are more at risk of developing LC (Thompson et al., 2022), cognitive dysfunction in those with unresolved and persistent symptoms has been reported in across age groups (Davis et al., 2021b) and regardless of formal LC diagnosis (Hampshire et al., 2024).

Electrophysiological measures of memory in healthy adults and patient groups

Electroencephalography (EEG) the event-related potentials (ERPs) derived from it have a high temporal resolution may be used to investigate neural functioning in a wide variety of conditions (Blinowska & Durka, 2006). EEG/ERPs may demonstrate functional disturbance even when structural imaging is normal and behavioural performance deficits are more subtle (Cecchetti et al., 2022; Furlanis et al., 2023).

EEG research in pwLC has found resting-state abnormalities similar to those with encephalopathy (Antony & Haneef, 2020; Cecchetti et al., 2022; Furlanis et al., 2023; Galanopoulou et al., 2020; Kopańska et al., 2021; Pasini et al., 2020; Yao et al., 2023). Some of these changes correlate with verbal memory deficits and may be temporary for some patients (Cecchetti et al., 2022) but sustained in others (Yao et al., 2023). Recent research has also associated LC with changes in ERPs related to face processing and auditory processing during a digit span task (Wojcik et al., 2023).

EEG / ERPs can also be used to explore cognitive processes related to memory in brain activity that people are not consciously aware of, such as implicit memories. Implicit memory has long been recognised as a core element of human cognition (Paller et al., 2012; Voss et al., 2012), but one that has been difficult to isolate from potential components of explicit memory processing (Addante et al., 2023, p. 202). In other words, items that are erroneously judged to be “new” rather than “old” may be missed because of their relatively weak explicit memory strength, which is not the same as a complete lack of awareness (e.g., Squire & Dede, 2015). Detecting levels of memory awareness for old and new items through confidence ratings when old new decisions are made (e.g., Yonelinas et al., 2010) allows researchers to equate memory strengths across items. This procedure removes the possible confound noted by Squire & Dede (2015) of the comparison between old and new conditions merely revealing differences in levels of explicit awareness rather than genuine implicit memory processes (e.g., Addante, 2015; Woodruff et al., 2006; Yu & Rugg, 2010, for recent review see Addante et al., 2023).

The ERP procedure developed by Addante (2015; 2023) equates old- and new status items (i.e. misses vs correct rejections) across confidence ratings and their comparison has highlighted parietal differences around 400-1000 ms after word onset that were both spatially and temporally separable from the mid-frontal old-new effect that typically occurs around 300-600ms after word onset (FN400). While midfrontal FN400 effects may be due to explicit familiarity or priming (e.g., (Mecklinger & Bader, 2020; Paller et al., 2012), the late parietal effects reflect differences solely due to contributions from implicit memory processing (i.e., from implicit repetition priming). As parietal (but not mid-frontal) old-new differences were reduced in hippocampal patients, Addante (2015) suggested that such patients have deficits in unconscious implicit memory processing (while effects of familiarity remain intact) and such reductions may be attributed to deficits in hippocampal function.

These findings are important because they firmly attribute implicit memory processing to the hippocampus, even though the medial temporal lobes and the hippocampus in particular had been thought of as far more crucial for explicit than implicit memory (Diana et al., 2007; Eichenbaum, 2017; Montaldi & Mayes, 2010; Suthana & Fried, 2012), with implicit memory more dependent on frontal cortical regions (Levy et al., 2004; Tulving & Schacter, 1990; Wagner et al., 2000). They suggest that implicit and explicit memory systems may function in different physiological ways but rely upon the same neural structures (Addante, 2015). The findings also provide compelling evidence to support the use of ERPs for differentiating the neural correlates of familiarity and recollection, implicit and explicit memory processes, item and source memory, and processing in people with and without memory deficits.

In sum, EEG / ERPs have been linked with hippocampal and frontal memory deficits, which make them a valuable method for delineating different subcomponents of memory-related brain activity (Ofen et al., 2019). However, although the measurement of healthy and disordered memory and cognition with EEG dates back decades (Beppi et al., 2021), no ERP study to date has investigated the memory subcomponents that may be affected in those pwLC who report persistent memory concerns.

Current Investigation

The aim of the proposed study is to use the same item- and source-memory confidence paradigm used in prior EEG/ERP studies of hippocampal patients (Addante, 2015; Addante et al., 2012; Addante et al, 2023) in order to characterise the various facets of memory and their neural correlates in those with Long Covid. Due to inflammation resulting from Covid-19, hippocampal damage and serious memory impairment is suspected in LC (e.g., Hampshire et al., 2024; Nouraeinejad, 2023) and to a less extent there may also be damage to the surrounding regions and prefrontal cortices. While memory loss and memory deficits are frequently reported by pwLC (e.g., Guo et al., 2022), the nature of these deficits and their neural correlates have not been systematically investigated. ERPs are a powerful method to access different levels of memory awareness, and will allow us to explore the extent to which pwLC's cognitive and ERP performance resembles those of patients with hippocampal damage. Several electrophysiological signatures of memory will be examined: mid-fronto-central FN400 (300-600 ms), implicit parietal repetition priming (400-1000 ms), left parietal LPC (600-900 ms) and central post-LPC wave (800-1200 ms). In addition, we will extend the research on hippocampal patients by also exploring whether memory deficits can be demonstrated electrophysiologically in pwLC already at encoding, as a result of impaired learning (i.e.., semantic or visual spatial encoding problems; Mecklinger & Kemp, 2023; Llana et al., 2024) or due to more general information processing deficits in LC. Two electrophysiological signatures of "subsequent memory effects" (SMEs) at encoding will be examined: an early frontal SME (300-1000 ms) thought to reflect the contribution of semantic processing to the encoding of verbal memories, which is mediated by both rhinal and left prefrontal cortex (e.g., Fernández-Castañeda et al., 2022; Otten & Rugg, 2001; for review see Mecklinger & Kemp, 2023). The other is a simultaneously elicited parietal SME (300-1000 MS) reflecting visuo-spatial imagery related to verbal processing, which is mediated by medial posterior parietal cortical regions such as the precuneus, and contributes to memory formation (e.g., Otten et al., 2002; for review see Mecklinger & Kemp, 2023). Prefrontal cortex and precuneus have reportedly shown alterations in pwLC (Clemente et al, 2023; De Luca et al, 2022; Li et al, 2023), comparable to patients with Alzheimer's disease (Chapuis et al., 2013).

Methodology

This study employs an independent group design for comparing survey scores in pwLC with those obtained from matched controls. Cognitive performance and electrophysiological measures will be assessed within participants, as well as compared between groups, through within-between factor interactions, based upon previously-established behavioural and ERP differences to old vs new words in basic recognition, ERP differences to in high and low confidence ratings for old and new words during retrieval, correct vs incorrect source memory performance, and ERP differences at encoding for words later retrieved vs forgotten.

Participants

Participants (*N* = 88) will range from 18-65 years of age (i.e., working age adults), with LC (*N* = 44) and age- and education-matched controls without LC (*N* = 44).This is a novel study as no research has yet produced ERPs of implicit and explicit memory processes in those with and without LC. Therefore, sample size was determined on the basis of an a priori power analysis of what we would consider meaningful group differences.

An a priori power analysis (G*Power) was conducted to estimate the required sample size using a small to medium effect size (f = .175), which is what can be expected based on within-participant effects seen in Addante et al. (2023), with power at .90 and an alpha of .02. A 2 (group) × 2 (ERP amplitude difference indicating a memory effect) repeated measures design for within-between interactions was used. The non-sphericity correction was set to maximum (1/m-1, where m signifies the number of measurements) and a moderate correlation between measures was assumed (r = .6). This resulted in an estimated sample size of 88 participants with an actual power of .90.

Therefore, we will recruit 48 participants in each group, which allows for up to 10% of potential exclusions based on data quality (see below). In the case that participants need to be excluded (see below) we will replace them until data from a minimum of 44 participants in each group have been acquired. This is a large sample size for an ERP study (average sample size per group is 21 in clinical studies; Clayson et al., 2019) and thus represents a significant improvement from previous studies of memory deficits (see also Addante et al., 2023, 2024).

Participants will be recruited via local LC clinics and LC-related social media accounts. We will only recruit participants if they meet the inclusion criteria of being aged between 18 and 65 years, English as first language or high command of the English language, and either suffering with persistent cognitive symptoms (specifically, memory concerns) following an earlier infection with Covid-19 (for the LC patient group) or reporting an earlier infection with Covid-19 but without lingering cognitive symptoms (post-covid recovered control group). Specifically, both groups will be required to complete a Covid-19 and a Long Covid questionnaire, which contains a symptom checklist and questions on the duration of symptoms. Only participants who meet the WHO criterion of having symptoms lasting longer than 12 weeks will be included as pwLC. The post covid recovered controls (matched on age, gender and years of education) will be required to have had symptoms lasting no longer than one month from their initial Covid-19 infection(s) and are not reporting symptoms now. We will prioritise pwLC who have a confirmed formal diagnosis with accompanying record, but will not exclude pwLC without formal diagnosis from the study. This is because memory deficits have been shown in those with unresolved and persistent symptoms regardless of formal LC diagnosis (Hampshire et al., 2024). Each participant will be reimbursed for their time with a £40 UK Amazon voucher.

After testing, we will exclude participants if they have not completed all parts of data collection or where it is clear that the task instructions were not understood or correctly followed (e.g., WCT performance close to chance level, which is 50%, and close to chance level on item recognition, which is 0%). (calculated as % hits - % false alarms). We will also exclude participants from ERP analyses if excessive noise in the EEG prevents the visualisation of the specific ERP components of interest (e.g., FN400, LPC) or an insufficient number of trials remains for conditions of interest following standard data preprocessing and averaging procedures (see below). In such cases, we will exclude participants on an analysis-by-analysis basis, in order to retain the maximum number of participants for other analyses (e.g., behavioural or survey data, other ERP components) with a minimum of 44 participants per analysis.

Ethics

Ethical approval for the study ("Implicit and Explicit memory in those with Long Covid-An EEG study") has been obtained from the University of Essex Ethics Sub Committee 3 (approval code: ETH2324-0957). As part of their ongoing research, the researchers have access to LC patients from the local area and funding for participant payment (£20 for 88 participants) has been granted by the University of Essex Department of Psychology.

Materials

Participants will read an information sheet about the study and sign a consent form; all other materials will be displayed using a computer screen or game pad.

Long Covid Questionnaire:

All participants will answer questions on demographics (age, sex, years of formal education received, ethnic background and present employment status) and questions related to previous Covid-19 viral infections, possible hospitalisation and treatments, and any longer-term symptoms, LC diagnosis they may have received, any medical aids or treatments they have used to help with symptom management and the effect on their daily lives. Symptoms will be selected from the NHS website (NHS, 2024). Participants will be asked to rank order them by severity and rate their impact on everyday life. For pwLC with a confirmed diagnosis, we will derive a Long Covid Severity Index (LCSI; Roberts et al., in preparation) based on the following information: number of months from the original Covid-19 infection, number of long lasting symptoms, and score on the adapted Post-Covid-19 Functional Status Scale (Klok et al., 2020) ranging from 0 (no limitations in everyday life) to 4 (severe limitations in everyday life). Higher LCSI scores indicate more long-lasting symptoms and lower independence in activities of daily living. When previously used (Roberts et al., in preparation), the LCSI ranged from 15 (least severe) to 68 (most severe) suggesting sensitivity to variation in symptom burden, however this measure has not been validated nor tested for reliability at this time.

Fatigue survey

Fatigue is a frequent and debilitating self-reported symptom in pwLC. Similar to previous research on pwLC (Kedor et al., 2022; Townsend et al., 2021), we will use the *Chalder Fatigue Scale* (CFS), which is reliable and internally consistent (Cella & Chalder, 2010), to assess fatigue in pwLC and controls. The CFS has both physical fatigue and psychological fatigue dimensions and includes questions such as “Do you have problems with tiredness?” and “Do you have difficulties concentrating?”. It consists of 11 items scored on a 4-point Likert scale from 0 (less than usual) to 3 (much more than usual). Scores range from 0 to 33, with higher scores indicating more fatigue. Previous use of the scale showed an average score of 24.4 (SD=5.8) in chronic fatigue syndrome, compared to a healthy sample score of 14.2 (SD=4.6) (Słomko et al., 2020).

Cognitive Failures

The Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982) will explore how often pwLC and controls experience errors of perception, memory and motor functioning in their everyday life. Example items include “Do you read something and find you haven’t been thinking about it and must read it again?”, “Do you drop things?” and “Do you fail to see what you want in a supermarket (although it’s there)?”. Participants respond to 25 questions using a 5-point Likert scale ranging from 0 (never) to 4 (very often). Scores range from 0 to 100, with higher scores indicating more frequent cognitive failures. Dimensions of forgetfulness, distractibility and false triggering will be extracted and compared between groups (Rast et al., 2008).

Quality of Life

Quality of Life is substantially impacted in pwLC (Davis et al., 2021), which we will assess with the *Quality of Life Scale* (QOLS; Flanagan, 1978) in pwLC and controls. The QOLS was designed for assessing populations with chronic illness and shown to be reliable and internally consistent across several studies (Burckhardt et al., 2003; Burckhardt & Anderson, 2003). It includes 16 items (e.g., understanding yourself, participating in active recreation) that require rating using a 7-point Likert scale from 1 (terrible) to 7 (delighted). Summed scores range from 16 to 112 such that a higher score indicates higher self-reported quality of life.

Word Task

Following Addante et al. (2012a), 216 unique words will be selected from the Medical Research Council Psycholinguistics Database (http:/www.psych.rl.ac.uk/MRCPsych Db.html). Words will be nouns, have an average rating of concreteness of 589 (min=400, max=670), imageability of 580 (min=424, max=667), Kucera–Francis Frequency of 30 (min=3, max=198), and an average number of 4.9 letters in each word (min=3, max=8). Participants will be presented with four blocks of 54 words, that are presented one by one, each written in white font on a black background screen. Two of the four blocks ask if words represent something manmade or not manmade (blocks A) and another block ask if words represent something alive or not alive (blocks B). Blocks are presented in one of two counterbalanced orders: ABBA or BAAB. We will measure and compare response speed and accuracy of word choice judgments between groups. We will also measure ERP components related to word encoding (mid-frontal wave and parietal P300-LPC wave) and compare them between groups and within-participants as a function of later recognition performance.

Procedure

All participants will be tested at the University of Essex Department of Psychology and Centre for Brain Science. Following consent, they will be fitted with an EEG scalp cap and ECG electrodes. After fitting an EEG cap and peripheral leads for referencing (earlobes), horizontal electrooculogram (HEOG) and electrocardiogram (ECG), participants will complete a *Word Task* in which semantic categorisations are made, a variant of which has previously been used as an incidental encoding task in patients with hippocampal damage (Addante et al., 2012a).

During encoding, participants will be given instructions to make a decision about the word presented on the screen. Subjects will be asked to make judgements about whether the item was manmade or whether the item described by each word is alive and conditions will be counterbalanced. The words will be presented on a black computer screen in white letters. To begin a trial, a screen with a small white cross at the centre will be presented for one of three randomly chosen interval times: 1, 2.5 or 3 seconds. Next the stimulus word will appear in the middle of the screen with “YES” presented to the bottom left of the word and “NO” presented to the bottom right of the word. The participants will be instructed to indicate their answer by pressing buttons corresponding to “YES” and “NO”. The stimulus will remain on the screen until a response is selected. After the participant responds, they will view a blank black screen at a random duration of 1, 2.5 or 3 seconds. After the blank screen, the small white cross will appear at the centre of the screen to begin the next trial. Poorer performance in the word has been reported in a memory impairment group compared to a control group (Neale et al., 2022), indicating the utility of the WCT when memory impairment is known or suspected.

After a break of around 45 minutes, during which participants complete two filler tasks, we will test participants’ explicit and implicit memory for the words shown in the word task and finally a retrieval task (old-new item- and source-memory with confidence ratings).

The *retrieval task* consists of the 216 words shown during the WCT and 108 new words, presented in random order over six blocks of 54 words each. For each word, participants are requested to select whether the word is old or new (item memory), and which list (manmade or alive) any words selected as old were from (source memory). In the old-new task, participants select between five response options to access item memory and item memory confidence. To begin a trial, a screen with a small white cross at the centre is presented for one of three randomly chosen times: 1, 2.5, or 3 seconds. Then participants will be presented with a word in the middle of the screen, the numbers “1,” “2,” “3,” “4,” and “5” evenly spaced beneath the word, the word “New” on the left by the number “1,” and the word “Old” on the right under the number “5.” Participants will be instructed to press any number between “1” and “5” to indicate if they confidently believe the word was old (“5”), believe the word was old but are not confident (“4”), do not know if the word was old or new (“3”), believe the word was new but are not confident (“2”), or confidently believe the word was new (“1”). Participants will be told to choose the response that most accurately reflects their memory. For old words, they are then asked to select between five further response options to assess source memory and source memory confidence. Participants press any number between “1” and “5” to indicate if they confidently believe the word was from the alive list (“5”), believe the word was from the alive list but are not confident (“4”), do not know if the word was from the alive or the manmade list (“3”), believe the word was from the man-made list but are not confident (“2”), or confidently believe the word was from the man-made list (“1”). We will measure response speed and accuracy for item and source memory, confidence, as well as ERPs related to familiarity (FN400, post-LPC wave), implicit repetition priming (parietal effect at 400-1000ms) and explicit recollection (LPC).

Participants will then be presented with a set of questionnaires lasting around 20 minutes. Finally, EEG cap and additional leads will be removed, participants wash their hair and are paid for their participation.

Due to their condition, pwLC may require frequent breaks. All tasks are blocked to allow for this. Control participants will be offered opportunities for breaks in the same manner and the total time taken to complete all the tasks will be recorded for each participant.

Electrophysiological Data Acquisition and Analysis

EEG/ERPs will be recorded at a 1000 Hz sampling rate using a Neuroscan EEG system with a Synamps2 amplifier (Compumedics, Victoria, Australia) and a 64channel electrode cap (Easycap GmbH, Herrsching, Germany) referenced to the right earlobe. Additional bipolar HEOG and ECG lead will be attached to the outer canthi of the eyes (HEOG), right clavicle and left hipbone (ECG), for monitoring purposes. Each participant will be tested individually and instructed to minimise head, face and eye movements as well as blinks. Electrode impedances will be kept below 30 kΩ.

To preprocess and analyse EEG/ERP data offline and match EEG/ERP findings for pwLC as closely as possible to those of previous research with hippocampal patients, EEG data will be re--referenced to the average of the earlobe electrodes, high--pass filtered at 0.1 Hz as a linear de--trend of drift components, downsampled to 256 Hz, and epoched from 200 ms before to 1200 ms after word onset and baseline corrected (-200ms to 0ms). Independent components analysis (ICA) using Infomax in EEGLab (Bell & Sejnowski, 1995) and visual inspection will be used to identify and remove artifacts like eye blinks and other aberrant electrode activity (trials exceeding ERP amplitudes of ±250 µV). Specifically, data will be first subjected to artifact correction (ICA), then to automated blink rejection via ERPLAB algorithm, and finally subjected to manual inspection for any residual artifacts that might have remained. Using the ERPLAB toolbox (Lopez-Calderon & Luck, 2014), we will apply a 30-Hz low-pass infinite impulse response (IIR) second-order Butterworth filter, and then average across trials for each condition of interest. In order to maintain sufficient signal--to--noise ratio (SNR), all comparisons will rely upon including only those subjects who meet a criterion of having a minimum number of 12 artifact--free ERP trials per condition being contrasted.

To ensure sufficient signal-to-noise ratios (SNR), only participants with a minimum of 12 artifact-free ERP trials per condition being compared will be included in all pairwise analyses. This criterion is used frequently in the literature (Gruber & Otten, 2010; Jenson & MacDonald, 2022; Otten et al., 2006; Ozubko et al., 2021), including previous reports of similar hypothesises (Addante et al., 2023; Addante et al., 2012a;

Addante et al., 2012b). The same preprocessing steps will be followed to derive ERPs to words presented during encoding.

Key Analyses

To test whether pwLC differ from controls in line with our hypotheses, we will use traditional behavioural and ERP analyses used for examining implicit and explicit memory processes in hippocampal patients and controls, as well as the Implicit Memory Analysis Pipeline (IMAP) to examine pure implicit memory processes (Addante et al, 2023). We will also use traditional behavioural and ERP analyses used for examining encoding-related processes as a function of correct or incorrect retrieval (Mecklinger & Kamp, 2023).

IMAP is an automated analysis tool for equating levels of memory awareness obtained from multiple response categories such as the confidence ratings of 1 to 5 for old vs. new judgments (Addante et al., 2023). IMAP randomly selects trials in an unbiased way across the two encoding task conditions (i.e. an equal number of trials per condition), and can bypass missing parameters in the analyses in cases where there are no data in one particular encoding condition (e.g. an insufficient number of responses from encoding task A are substituted with trials from encoding task B). Addante et al. (2023) showed that the effects derived from this procedure are not driven by explicit recollection or familiarity. Specifically, they showed that the IMAP findings remained unchanged even when they systematically removed explicit memory confidence categories from the IMAP procedure's contrasts. This test validated that the IMAP effects truly capture implicit memory activity without any potential conflation from explicit memory.

Bayesian tests will be used for null and alternative hypotheses as this will allow us to delineate their relative evidence (Dienes, 2021). As an example, with a .02 significance level, a Bayes Factor (BF) greater than 6 or less than 1/6 would indicate an effect of the alternative hypothesis (i.e.., H1-H12 in cases where a difference is expected), whereas a BF between 1/6 and 6 would indicate the inability to distinguish between alternative hypothesis and H0, or as evidence for the null hypothesis in cases where no difference between groups is expected. The BF of 6 has been chosen over the conventional criterion of 3, as this is a requirement criterion to submit to Cortex (Dienes, 2021). Therefore, we will consider BF >6 or <0.16 for the alternative hypotheses and BF between 0.16 and 6 will be considered evidence for the null hypotheses.

The proposed analyses for each hypothesis and specific statistical comparisons are described in Table 27.

Table 27. Hypotheses and Analyses

Primary Hypotheses	Secondary hypotheses
We expect pwLC to demonstrate deficient explicit recollection effects (left parietal LPC; 600-900ms after word onset) compared to controls. Item recollection will be quantified in two	We expect both pwLC and controls to demonstrate mid-frontal effects of familiarity (FN400; 300-600ms after word onset). Item familiarity will be quantified in two different ways: basic

Primary Hypotheses	Secondary hypotheses
different ways and we expect LPC waveforms for hits (old items judged as old) and for high confidence items (“5”) to be significantly more positive at left parietal electrodes (P5, P3, P1, PO3) than the LPC waveforms for correct rejections (new items judged as new) and low-confidence items (“4”), only for the control group, but not for pwLC Hypothesis an interaction between condition (hits vs crs, high vs low confidence) and group, follow up with planned t-tests comparing conditions for each group. Expect significant difference between conditions for controls, no significant difference for patients in t-test. In addition, we will calculate BF to show evidence for null hypothesis in patients (ie., BF<0.16).	differences between hits (old items judged as old) and correct rejections (new items judged as new), and more specifically in terms of a contrast between correct high and low confidence decisions. Thus, we expect the FN400 for hits and for high-confidence items to be more positive significantly more positive at mid-fronto-central electrodes (FC3/4, FC1/2, FCz, Fz, Cz) than the FN400 for correct rejections and for low-confidence items. We also expect neither of these differences to differ between groups of pwLC patients and controls. Hypothesis a main effect of condition, hypothesis no interaction between condition and group, follow up with planned t-tests comparing conditions for each group. Expect significant difference between conditions for controls and patients.
We expect pwLC to demonstrate deficient source memory (parietal LPC; 600-900ms after word onset) compared to controls. Specifically, we expect the LPC for correctly remembered sources (i.e., old items leading to high or low confidence correct source responses) to be significantly more positive over left posterior parietal electrodes (P5, P3, P1, PO3) than the LPC for incorrectly remembered sources (i.e., old items that	We expect both pwLC and controls to demonstrate mid-frontal effects of familiarity in source memory (FN400; 300-600ms after word onset). Specifically, we expect the FN400 for correctly remembered sources to be significantly more positive at mid-frontal electrodes than the FN400 for incorrectly remembered sources, and for this difference not to differ between groups. Hypothesize a main effect of

Primary Hypotheses	Secondary hypotheses
received either a source incorrect or a source unknown response), only in controls but not in pwLC. Hypothesis an interaction between condition and group, follow up with planned t-tests comparing conditions for each group. Expect significant difference between conditions for controls, no significant difference for patients in t-test. In addition, we will calculate BF to show evidence for null hypothesis in patients (ie., BF<0.16).	condition, no interaction between condition and group, follow up with planned t-tests comparing conditions for each group. Expect significant difference between conditions for controls and patients.
We expect pwLC to demonstrate deficient implicit repetition priming (parietal differences 400-1000ms after word onset) compared to controls. Specifically, we expect waveforms for old items to be significantly more positive over bilateral posterior electrodes (CP3/4, CP1/2, CPz, P3/4, P1/2, Pz, PO3/4, Pz, O1/2, Oz) than waveforms for new items (H73a), only for the control group, but not for pwLC. Implicit memory contributions will be measured both traditionally (ERPs for misses - old items incorrectly endorsed as new – compared to ERPs for correct rejections of new items endorsed as new) and after applying the more rigorous IMAP, for which effects are expected to extend into longer latencies in right parietal regions (Addante et al.,	We expect pwLC to demonstrate intact contextual familiarity effects in source memory (post-LPC wave; 800-1200ms after word onset). Contextual familiarity will be quantified as low-confidence hits with correct source recognition vs correct rejections. We expect the post-LPC wave for low-confidence hits to be significantly more negative at central electrodes (Cz), where this widespread fronto-central-parietal negative-going effect is maximal (Addante et al., 2012; Addante et al., 2024), than the post-LPC wave for correct rejections. We also expect this context familiarity effect not to differ between pwLC patients and controls. Hypothesize a main effect of condition, no interaction between condition and group, follow up with planned t-tests comparing conditions for

Primary Hypotheses	Secondary hypotheses
2023, 2024). Hypothesize an interaction between condition and group, follow up with planned t-tests comparing conditions for each group.	each group. Expect significant difference between conditions for controls and patients.
	We expect pwLC to demonstrate significantly reduced item memory performance (proportion of hits - old items judged as old - minus proportion of false alarms - new items judged as old) than controls but significantly better than chance. Analyses will first consider both low and high confidence responses and second consider high-confidence responses only. High-confidence responses are more likely to be indicative of recollection, which we expect to be more deficient than effects indicative of familiarity. T-tests comparing groups expected to be significant. We expect pwLC to demonstrate significantly reduced source memory (number of correctly attributed sources divided by the sum of correctly and incorrectly attributed sources, excluding source-unknown responses; Addante et al., 2024) than controls, and that their source memory does not differ from chance. Analyses will first consider both low and high confidence response and second consider high-confidence responses – more indicative of

Primary Hypotheses	Secondary hypotheses
	recollection than familiarity - only. T-tests comparing groups expected to be significant. T-tests against chance expected to be not significant. Follow with BF<0.16 to show evidence for null.

An alpha level of *p* =.02 will serve as evidence of a significant difference. A Bayes factor of <0.16 will serve as evidence for absence of differences between conditions in pwLC. Furthermore, a recent study (Sun et al., 2024) proposed response-locked analysis to better discern the parietal recollection effect (LPC). We will add such an analysis to the aforementioned standard stimulus-locked analysis of this ERP component. We will not expand on these supplementary analyses further here.

Expected Results

Although this is a novel study for those pwLC, we expect that pwLC would show similar behavioural and ERP results to Addante at al.'s (2012) patients with amnesia from mild hypoxia, with impaired implicit item memory and source memory compared to controls (Addante, 2015; Addante et al., 2023). We also expect measurable behavioural and ERP differences during incidental encoding stages, indicating less efficient processing of verbal material in behavioural performance and reduced reflections of subsequent retrieval (SMEs) in ERPs (Mecklinger & Kemp, 2023). Finally, we expect pwLC to differ from controls in their survey responses regarding everyday cognitive symptoms and perceived wellbeing.

This study will offer novel insights and contributions to LC and broader memory research. A systematic review (Tavares-Júnior et al., 2022) highlighted the high frequency of cognitive impairment after COVID-19, and this study will enable us to support or reject the hypothesis that LC is associated with specific electrophysiological markers of memory impairments. It allows us to delineate which specific memory components are impaired or intact (semantic and/or visual-spatial encoding, item and source memory, explicit familiarity, explicit recollection, and implicit contributions to recollection). As explicit recollection (i.e., correct item memory bound within the context it was experienced) relies on the hippocampus and other medial temporal lobe structures, we hypothesised to find recollection deficits in pwLC (Addante et al, 2012; Addante, 2015) similar to patients with amnesia because hippocampal damage has been shown also in pwLC. Recent studies suggest that implicit item processing (measured traditionally as comparisons between misses and correct rejections and more recently as pure implicit repetition priming effects) may also be mediated by the hippocampus, though in physiologically different ways than explicit recollection. We therefore hypothesised that pwLC would also exhibit reduced implicit retrieval of word items, similar to hippocampal patients.

Theoretical models of memory propose that effects of explicit familiarity (item and context familiarity) and implicit repetition priming may also rely upon other medial temporal lobe structures, such as the entorhinal and parahippocampal cortices (Buckner et al., 2000). Since these are thought to be affected, albeit to a lesser extent than the hippocampus in pwLC (De Luca et al, 2022; Douaud et al, 2022) we hypothesised that familiarity effects may be intact in pwLC, again similar to hippocampal patients with amnesia. However, since Douaud et al. (2022) showed reduced cortical thickness and contrast of grey matter in the parahippocampal gyrus in pwLC, it is also possible that the familiarity effects measured in our study are also compromised in pwLC. In addition, it is possible that the hypothesized impaired implicit repetition priming in pwLC is due to deficits not just in the hippocampus but also in entorhinal and parahippocampal cortices.

Chapter Six: General Discussion

This thesis used of a mixed methods approach design, collecting cognitive performance data assessed with both self-guided tasks and examiner administered tasks, and qualitative data through survey responses and semi-structured interviews, aiming to explore the long-lasting nature of LC cognitive deficits and symptom trajectory in a working age sample. A summary of findings across all studies is presented in Table 28

Table 28. Summary of findings

Hypotheses	Quantitative Findings	Qualitative Findings
Short Term Memory	Not directly measured	STM issues reported by 70%. Reports of forgetting on a daily basis and inability to hold conversations. Memory fluctuates with symptoms such as fatigue.
Long Term Memory and Consolidation	Impaired performance on Long Delay tasks but no evidence of Accelerated Long-Term Forgetting. Some improvements over time.	Future and past event recall largely preserved. Some gaps in LTM, particularly recent LTM. Memory fluctuates with symptoms.
Episodic Memory	Impaired recall on Story Recall, List Learning and Word and List Recognition.	Effortful retrieval and gaps in personal memory.

Hypotheses	Quantitative Findings	Qualitative Findings
Semantic Memory	Intact categorisation and intact semantic knowledge.	Word finding issues and problems with semantic errors while reading.
Procedural Memory	Not directly assessed.	Difficulty with routine tasks such as driving and using technology.
Spatial / Visual Memory	Preservation of visual memory.	Disorientation and navigation problems. Impact on independence.
Processing Speed	Impaired SOIP.	Slowed thinking and difficultly keeping up with conversations.
Fatigue	CFS score significantly higher than controls over time. Fatigue predicted performance in Story long delay, high-confidence false alarms, item and source memory in the LMM analyses.	Unpredictable and persistent fatigue causing ‘crashes’, similar to PEM.
Quality of Life	Significantly lower QoL than controls throughout. No improvement over time.	Grief, loss and isolation. Loss of identity.

Hypotheses	Quantitative Findings	Qualitative Findings
Daily Limitations	Higher LC severity predicted more limitations. Some reduction over time.	Reduced abilities to work, socialise and manage own care needs.
Acute Severity	Not a predictor of cognitive performance in isolation. Interacted with Fatigue and LC Severity to affect performance on story recall long delay, item and source memory.	Some made references that participants were better than before (i.e. compared to when they first became unwell).
Long Covid Severity	Higher LC Severity resulted in poorer performance on word recognition and source memory tasks. Impacted daily functioning. Interacted with Fatigue and Acute Severity on story recall long delay, item and source memory.	LC symptom burden on everyday life, loss of independence and frustration at length of time to recovery.

As highlighted in Table 28, there were both some alignment and contrasts between the quantitative and qualitative results. The results for processing speed, fatigue, quality of life and daily functioning align across the data. They showed consistent performance impairments of LTM, semantic memory and spatial / visual memory that are consistent with lived experiences.

Additionally, the themes discussed in Chapters Two and Three highlight the lived experiences for pwLC. Namely; the sense of loss and multitude of emotions, unpredictable and debilitating symptoms, lack of support, cognitive challenges, managing expectations and continued uncertainty, social isolation, the ongoing impact of LC, reinfection and the consequences, barriers to medical support, personal resilience and adaptation, the realities of living with LC, uncertainty of self and the future, strategies to manage memory difficulties and the use of analogies.

The results of the series of studies described in this thesis, provide evidence that memory, identity and independence, among other areas, are negatively affected by LC for up to 60 months post-acute infection. Additionally, the findings demonstrate the nonlinear recovery trajectories for pwLC and reflect the need for long-term multidisciplinary support.

Interpretations of Findings

The cognitive impairments observed within this thesis align with LC literature, which has identified that memory, executive function and processing speed are commonly impaired in pwLC (Nasir et al., 2025; Tavares-Junior et al., 2022; Bertuccelli et al., 2022; Miskowiak et al., 2022) as hypothesised in Table 2. These impairments are evident in a sample of pwLC of a working age, providing evidence into research that suggests a cognitive impairment as a significant risk in the working-age population (d’Ettorre et al., 2022).

The pwLC within this study showed encoding deficits and difficulties recalling information which may be attributed to attentional disruption or, difficulties in consolidation. This aligns with Atkinson and Shiffrin’s Multi-Store model (Atkinson & Shiffrin, 1968). However, given the interactions observed in the LMM, fatigue may affect encoding and reduce depth of processing for pwLC. PwLC may have more shallow processing of information which aligns with the levels of processing memory framework (Craik & Lockhart, 1972). The model suggests that deeper processing leads to better retention and thus memory recall, which may suggest that fatigue may limit the ability to encode information, which could contribute to the memory difficulties observed.

Executive function difficulties that were prominent in participants’ interview responses in Chapter Three, such as sequencing concerns, may be contributing to the reduction in daily function that were also consistently reported. Reduced ability to sequence everyday tasks is often observed in dementia / patients with neurodegenerative conditions associated with semantic impairment (Henry et al., 2004). Executive function in pwLC have been previously reported quantitatively (GarciaSanchez et al., 2022; Mazza et al., 2021) and through qualitative accounts that discuss the everyday challenges of living with LC (Callan et al., 2022; Humphreys et al., 2021). As discussed in the introductory chapter, deficits in executive function are likely to result in functional consequences, as it supports planning, problem solving and sustaining attention (Gilbert & Burgess, 2008). However, executive function was not directly measured in this thesis, but a number of aspects of performance on tests and the lived experiences indicate this may be an issue for pwLC, but further research is required to explore this and how it progresses over time.

Although there were no direct tests of working memory and visual memory was intact in the examiner administered tasks, pwLC reported signs of executive dysfunction in the lived experience data, which may indicate the working memory model's different components (Baddeley & Hitch, 1994), namely the central executive, phonological loop and the episodic buffer. The findings suggest that pwLC have difficulties in multitasking, attention and executive dysfunction, which could reflect a reduced capacity of the central executive system. The reported difficulties with verbal rehearsal and reading and the concerns raised regarding spatial navigation may suggest problems with working memory, however visual memory appeared intact with performance of quantitative visual memory tasks. This is consistent with reports of milder visual memory deficits in pwLC (Delgado-Alonso et al., 2022; Zhao et al., 2022). This may suggest the visual memory is selectivity spared in pwLC, which has previously been reported (Carmona-Cervelló et al., 2024). This may be attributed to the neural basis of visuospatial cognition, which relies on posterior cortical regions, two specific cortical streams, the dorsal visual pathway and the ventral visual pathways (Goodale & Milner, 1992; Mishkin & Ungerleider, 1982). It may these regions and pathways, are less affected by neuroinflammatory responses to Covid19 (Carmona-Cervelló et al., 2024).

While language difficulties have been less explored in pwLC (Bertuccelli et al., 2022), some evidence was found in this thesis. The word finding difficulties and slowed speech, reported in the interviews (Chapter Three), aligns with previous LC research that have found similar difficulties (Chambers et al., 2023; Cummings, 2024; Gilheaney et al., 2023; Woo et al., 2020).

The evidence of impaired processing on tests described in Chapter Two and difficulties with attention self-reported in Chapter Three, align with research showing persistent slowing and sustained attention deficits (Delgado-Alonso et al., 2022; Hampshire et al., 2021; Martin et al., 2024). However, the present findings do contrast with research reporting recovery of processing speed in pwLC 12 months post-infection (Ferrucci et al., 2022), as many participants tested for this thesis demonstrated persistent impairments. Although the longitudinal analyses revealed improvements over time, impairments on this domain were still evident at Assessment Three, with poorer performance than controls and prevalence of impairment, which was an average of 24 months from the initial assessment and an average of 44 months since acute infection.

Immediate and delayed recall memory performance was also consistent with previous LC literature (Crivelli et al., 2022; Ferrucci et al., 2022; Llana et al., 2024). While evidence of improvement over time on story delayed recall supports the possibility of some recovery in verbal memory (Ferrucci et al., 2022), these findings contrast with reports of recovery of verbal memory within 12 months (Cecchetti et al., 2022; Diana et al., 2023). The difference between the findings of this thesis as those of Cecchetti and colleagues may reflect methodological differences, including recruiting participants online rather than hospitalised patients. The hospitalised patients may not have gone on to develop LC therefore the acute effect upon verbal memory may have been quicker to recover. Furthermore, practice effects for this task might explain why performance increased. However, the *T*-scores for change reported in Chapter Two, suggest that practice effects are less likely to have impacted performance. This thesis found deficits in verbal memory persisting beyond one-year post-infection, however, there was no evidence to suggest accelerated long-term forgetting, as pwLC did not forget proportionally more information than the normative data.

Some participants reported intact older memories, whereas others described difficulties and gaps in their more recent memories, particularly for events that had happened post-infection. These reports were supported by the quantitative data that indicated pwLC retain little information over time. However, most participants who took part in the autobiographical interview were able to recall past events (LTM), which was scored based on the level of detail they provided, in different categories such as semantic elements. This consistent with the theories set out by Ribot and Jost. Ribot’s law suggests that older memories (LTM) are often better preserved than more recent memories, particularly in those with have neurological damage, Jost’s law supports that older memory decays more slowly than more recent memories. In pwLC this may reflect disrupted encoding and consolidation, whereas older memories may have already consolidated prior to LC. Furthermore, factors such as fatigue, may disrupt formulation of new memories.

While the poor performance found in verbal recognition aligns with research findings of impaired recognition (Becker et al., 2021; Graham et al., 2021), semantic categorisation remained relatively preserved. The impaired recognition but intact semantic skillsaligns with research suggesting semantic knowledge is more resilient to neurological disruption (Patterson et al., 2007; Ralph et al., 2017). This may suggest that the impairments identified within this thesis are more likely attributable to LC neurological or inflammatory processes rather than pre-morbid semantic deficits.

As discussed in Chapter One, the underlying mechanisms for cognitive impairments in pwLC are not yet fully understood. There is evidence to suggest direct and indirect neuroinflammatory and immunological processes may be implicated. Previous LC research has indicated that the hippocampus in pwLC is damaged (Greene et al., 2024; Hampshire et al., 2024; Nouraeinejad, 2023). The memory deficits found in this thesis are consistent with existing evidence of damage to the hippocampus in this population. The medial temporal lobe, particularly the hippocampus are thought to be critical for memory consolidation (Alvarez & Squire, 1994) and the findings of this thesis may offer indirect support for this for pwLC. The hippocampus is responsible for forming memories in their spatiotemporal context (Burgess et al., 2001), episodic memory recall (Behrendt, 2013) and spatial navigation (Behrendt, 2013) and it further contributes to a sense of identity (Meyer et al., 2025). Damage to the hippocampus may offer a neurophysiological explanation for the episodic memory difficulties and disrupted identity experiences reported by pwLC in these studies.

The reported findings also align with the standard consolidation theory (Bayley et al., 2005), which suggests the medial temporal lobes (MTL), including the hippocampus bilaterally, are involved in encoding, storage and recall of semantic and episodic information, but only for a limited time. The participants within this research demonstrated impaired episodic memory which may also further suggest disruption in consolidation. The preservation of some LTM, evident in the semi-structured interviews, is consistent with the theory, that once consolidated, older memories no longer rely on the MTL. Participants qualitatively reported difficulties recalling recent STM, and while STM was not directly tested quantitatively, poorer immediate recall performance of pwLC compared with controls, may suggest potential impairment in STM, however further research specifically testing STM is required. The frequent reported use of memory aids to support information retention, demonstrates this is a concern for pwLC. The qualitative reports of better access to LTM compared to more recent memories, supports the standard consolidation theory and the time limited role of the MTL.

Within the LC literature, there is recognition that LC can increase the incidence and progression of neurodegenerative diseases (Miners et al., 2020) including Parkinson’s (Hein et al., 2025) and Alzheimer's disease (Baazaoui & Iqbal, 2022; Chambers, 2023), which is a concern for the future trajectory of LC patients. While the findings in this thesis do not contribute or offer any direct evidence of this, they do demonstrate the persistent cognitive and functional difficulties up to 60 months post-acute infection and evidence of nonlinear recovery trajectories, an important consideration for the future of LC. The long-lasting nature of LC with little recovery over time, may suggest that LC patients are at higher risk of developing neurodegenerative diseases later in life. Research has shown that severe inflammatory reactions and aging are common links between Covid-19 and neurodegenerative diseases (Baazaoui & Iqbal, 2022). Furthermore, the long-lasting effects may impact the nervous system directly (Strong, 2023) which could potentially increase the risk of physical neurodegenerative symptoms to develop. Further research is required exploring the risk of neurodegenerative diseases in pwLC, to ensure the burden of the acute and ongoing nature of Covid-19 observed over the last five years, is not repeated in years to come with increased patients with neurodegenerative diseases.

Another interesting theoretical link between pwLC and potential hippocampal damage, is that although participants did not directly describe a loss of spatial-bodily sense of self, many described an altered sense of self with terms such as feeling “like a different person”, “not trusting myself” and no longer feeling “normal,” a psychological difference. These descriptions informed themes relating to uncertainty and loss of former self in the thematic analyses, and suggest a loss of identity. These were often combined with a decline in functional autonomy including concerns with cooking, driving and remembering appointments. Some participants referred to themselves as a “liability” and feared unintentionally hurting themselves which suggest that the memory impairments observed within this thesis are not isolated to cognitive deficits but also include safety and identity concerns. The loss of self may reflect neurocognitive mechanisms, particularly in the hippocampus and the entorhinal cortex. These are vital, not only for memory processes, but also for self localization in time and space (Peer et al., 2015; Robin, 2018), which supports episodic recall, mental time travel and the embodied sense of self.

Alongside the links to loss of self-uncovered during the thematic analyses, pwLC also described extreme fatigue and brain fog while trying to encode information. The work by Meyer and colleagues (2025) may suggest that they have reduced hippocampal involvement during memory formation. Although some aspects of semantic memory such as the semantic categorisation of words remained intact, qualitative accounts revealed word-finding difficulties and loss of orientation, indicating partial disruption. These interpretations may provide an explanation for the memory impairments and reduced sense of self that participants described, and may also indirectly support previous suggestions that the hippocampus is damaged in pwLC. As the hippocampus is not only important for episodic memory encoding but also for linking memory to a sense of self through premotor-hippocampal coupling. Recent research has found that premotor-hippocampal coupling and the sense of agency during encoding predict the vividness of memory recall (Meyer et al., 2024a; Meyer et al., 2024b). This suggests encoding without a sense of bodily presence or self-agency (i.e. sense of self), results in reduced premotor-hippocampal coupling, thus reduced hippocampal activation and less memory recall. A further study by the same authors suggests that bodily perception links memory and sense of self and this was evident in hippocampal amnesia patients who had experienced disruptions to their sense of identity (Meyer et al., 2025). One possible interpretation is that pwLC may have a disruption between hippocampal and premotor coupling, that is potentially contributing to memory difficulties described and measured, but also their sense of self.

The results from the word categorisation and recognition task that was based on and adapted from a study by Addante and colleagues (2012), had elements that both aligned and contrasted with Addante et al.’s findings with patients with amnesia, following hypoxia and traumatic brain injury (TBI). The original study reported that patients had deficits in recollection (high-confidence item recognition and source recognition performance) but familiarity (low-confidence item recognition) was spared (Addante et al., 2021a), supporting previous work on the dual process model of recognition memory, which claims that recollection and familiarity are distinct memory processes (Yonelinas et al., 1996). Addante et al.’s results support previous research that reports recollection relies upon the hippocampus, whereas familiarity can be supported by surrounding MTL cortex (Eichenbaum et al., 2007)

The authors found that item (word) recognition was intact, and source memory was impaired. In our findings word recognition memory was preserved, with no differences between pwLC and control participants. However, pwLC had reduced high confidence for item memory, suggesting reduced certainty, an element of the results which does align with patients with hippocampal damage (Addante et al., 2012a).

However, unlike Addante et al.'s patients, pwLC in this study's sample did not demonstrate impairments in source memory for the self-guided task but they did for the examiner administered task. The findings may suggest context specific impairments rather than global recollection deficits. A possible explanation for this, as discussed in Chapter Two, is the compensatory strategies participants may have used in the self-guided task, in comparison to what they were able to use in the examiner administered task, which was faster paced.

The preservation of source memory was also evident with high- confidence judgements in pwLC and participants scored above chance, which suggests intact binding between item and source memory for this task. This contrasts with Addante and colleagues' patients (2012a), as their patients did not demonstrate high confidence judgements in source memory. However, the three-way interactions found in the longitudinal analyses did demonstrate that fatigue, acute and LC severity, in combination, all had a negative effect upon source memory performance, which may help to explain the differences to the performance in Addante et al.' study.

This is evidence that pwLC performance was affected by other factors (fatigue and severity), that were not measured in patients with hippocampal damage. Additionally, patients with LC may have built more sufficient strategies to support their memory than patients with hippocampal damage, particularly as two of the patients in Addante et al.'s study had traumatic brain injury. Rehabilitation for patients with TBI encourages the use of internal and external compensatory strategies for memory impairments (Velikonja et al., 2014) and while there is no evidence participants in this study have engaged in such rehabilitation, the self-reported narratives of adaptation in the semi-structured interviews, suggest participants were open to adaptation. This adaptation may have included strategies to help compensate memory.

Our findings differ to the work by Addante and colleagues. (2012a), the contrasts identified may reflect specific task-related impairments rather than global deficits. The reduced clarity for item recognition that was demonstrated by pwLC, that aligned with patients with hippocampal damage, may suggest a disruption to familiarity processes, which is supported by the MTL cortex (Eichenbaum et al., 2007). This may suggest that pwLC do not have hippocampal damage, instead they present with recollection variation between different source related tasks. This variation as direct impact of LC may be compensated for when strategies are employed. The results could reflect functional dysregulation rather than permanent hippocampal damage; however further research is required to delineate this in pwLC.

More broadly, the findings also align with previous longitudinal LC research that has found on going fatigue with slow recovery (Vallée et al., 2025), persistent fatigue, memory and concentration difficulties (Helmsdal et al., 2022) and persistent cognitive deficits (Yeung et al., 2025). Furthermore, Yeung and colleagues (2025) reported many participants with LC were unable to work, thus had financial distress, and also experienced an impact of LC on their daily activities and difficulty in getting medical professions to take symptoms seriously. Importantly, all of these aspects were echoed by participants within this thesis.

As discussed, the interpretation with the reduced sense of self, the descriptions by pwLC align with the illness identity theory (Oris et al., 2016). PwLC who participated in the studies within this thesis, often used terms such as feeling “unreliable” and “not normal” which reflects the identity disruption they are facing. For some pwLC, being unwell with LC dominated their identities, aligning with elements from the illness identity theory (acceptance, rejection, engulfment and enrichment). The illness identity theory describes how being chronically unwell can become integrated into a person’s sense of self. The loss of autonomy and impacted identity identified in the results, provide direct evidence that not only is LC impacting memory but also shaping identities of pwLC. The illness identity theory (Oris et al., 2016) helps to understand with why pwLC adapt and how self-management can be important.

The change of identity and sense of loss described in this thesis are consistent with findings from other patient groups including those with acquired brain injury (ABI) and chronic illnesses. ABI patients often have a sense of loss of self, comparing themselves post injury to their former selves and often struggle with the new labels that society imposes upon them (Nochi, 1998). Perceived identity change in those with ABI has been associated with grief and depression (Carroll & Coetzer, 2011). Similarly, those with neurodegenerative diseases have described ambiguous or ongoing grief due to losses in cognitive abilities, independence, identity and future life roles (Boss, 1999).

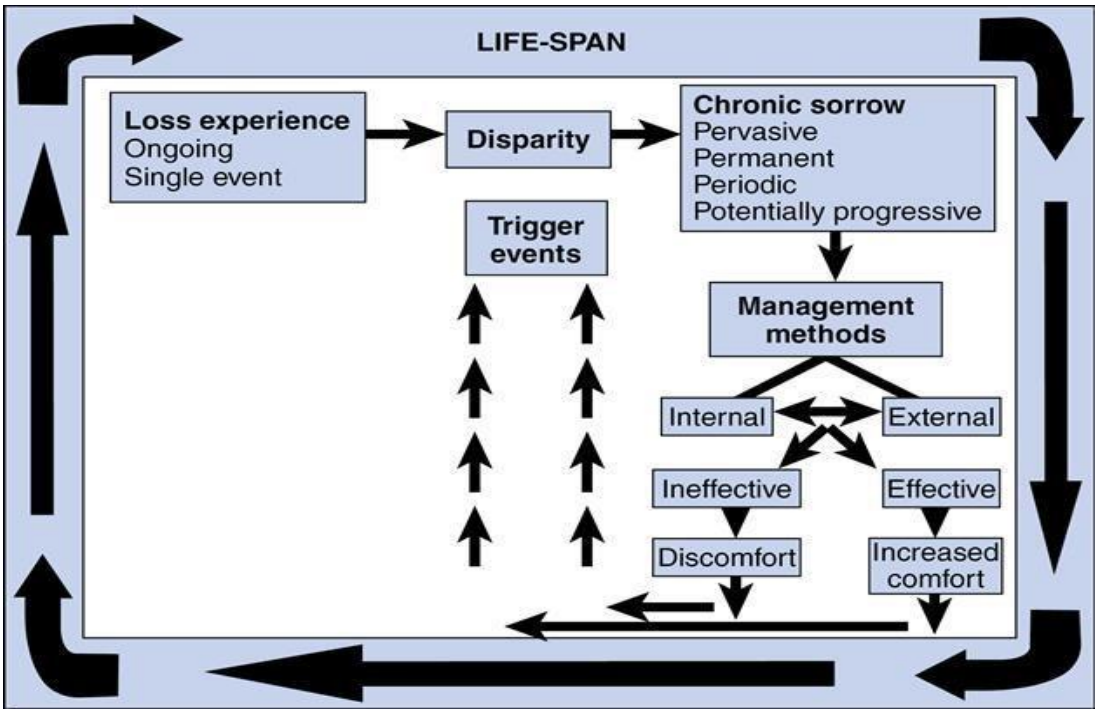
The concept of self-management has been explored in patients with chronic conditions and highlights how individuals monitor and respond to symptoms, maintain functioning and manage the emotional impact of the condition (Wright et al., 2003). PwLC described the variety of strategies they used to self-manage their LC.

These ranged from pacing to reframing their own expectations. However, given the unpredictable nature of LC symptoms including debilitating fatigue, these strategies were not always successful. Participants spoke about the trial-and-error learning they had made throughout their LC journeys. Furthermore, the concept of self-management has been explored in patients with chronic conditions and highlights how individuals monitor and respond to symptoms, maintain functioning and manage the emotional impact of the condition (Wright et al., 2003). In sum, self-management in pwLC shares commonalities with other patient groups, including the need to pace, as described as important for pwME / CFS in the introductory chapter. However, self-management for pwLC is complicated and presents challenges due to the unpredictable and fluctuating LC symptoms. PwLC within this thesis, referred to this fluctuating day by day and hour by hour.

Many pwLC described their sense of loss, grief, identities as well as mourning their former lives. This sorrow was triggered and often reactivated when they were faced with reminders of things they could no longer participate in such as work and socialisation. This is further evidence to suggest that the findings from this thesis extend beyond the cognitive impairments that were directly measured. This finding also aligns with research into pwME / CFS who have identity disruption and perceived loss of control (Asbring, 2001). PwME / CFS have reported how this disruption has impacted their identity at work and within their social lives (Asbring, 2001), alongside describing coming to terms with new identities. These impacts are echoed by pwLC within this thesis.

The theory of chronic sorrow (Eakes et al., 1998) highlights the persistent grief experienced by patients of chronic conditions, as they face ongoing loss and changes to their self-concept. The feelings described and terms used by pwLC within this thesis, reflect a sense of loss and the emotional burden of this loss, which are consistent with this model. Additionally, pwLC reported having to re-adjust, reconsider pacing and adjust their expectations throughout their LC journeys, which aligns with the cyclical nature of the model of chronic sorrow, as shown in Figure 47.

Figure 47. Theoretical Model of Chronic Sorrow (Eakes et al., 1998)



However, it should be acknowledged that while the longitudinal data suggests nonlinear recovery that could trigger the sorrow cycle, sorrow was not directly measured but captured from the participants lived experiences. Additionally, some participants did describe acceptance and resilience, while others described continued uncertainty, therefore this model might not be appropriate for all pwLC.

The results from both the quantitative and qualitative analyses may provide evidence to suggest disruption in each of the biopsychosocial model's elements. The biopsychosocial model of illness (Engel, 1977) that proposes illnesses are not just a biological process but also shaped by psychological and social elements, which is relevant to pwLC due to the multifaceted impact of LC that is evident. On a biological level, the evidence of cognitive impairments, alongside debilitating fatigue and reports of PEM observed within, are similar to those observed with ME / CFS (Dehlia & Guthridge, 2024; Wong & Weitzer, 2021). This may suggest that the underpinnings of these conditions such as neuroinflammation, neural disruptions within the MTL and hippocampal vulnerability, may also be involved in pwLC. These potential biological disruptions interact with psychological factors. Participants described different psychological aspects to living with LC, such as anxiety, fear and reduced sense of self and some described emotions that are consistent with chronic sorrow and identity loss frameworks as discussed. Furthermore, there were several social elements to the LC journey. The participants described how LC had impacted their work and social lives, alongside their independence. The stigma and barriers to care, alongside the lack of access to specialist services raised inference regarding health inequality. The findings within this thesis, suggest the biopsychosocial model of illness is very relevant to pwLC, as the potential impact to biological underpinnings can undermine psychological wellbeing and play a role in the social impacts.

To summarise, from the results across of the studies, it is evident that pwLC experience persistent cognitive impairments, which provide indirect support for different existing models including the levels of processing framework, the illness identity theory, the chronic sorrow theory and the biopsychosocial model. Additionally, the results and interpretations are consistent with existing research implicating hippocampal deficits in pwLC (Nouraeinejad, 2023). The findings have provided answers to the research questions, which will next be discussed.

Implications and Recommendations for Interventions

Research Implications

The findings, both quantitative and qualitative, throughout this thesis have addressed the research questions illustrated in Figure 2.The findings to those questions are presented Table 29.

Table 29. Thesis Research Questions

Research Question	**Findings**
What are the long-lasting memory and learning consequences of LC on the working age population?	Persistent memory and learning impairments over 24 months, particularly with episodic memory, verbal learning and rehearsal.
Do LC deficits vary across domains?	Deficits were mostly domain specific. Short term memory and verbal memory was impaired, as was long delay recall and episodic memory. Visual memory was intact and there was no evidence of accelerated forgetting. Qualitative data aligned with reports of strengths and limitations across domains.
Do these deficits change over time?	Both the longitudinal analyses using the LMM and patient reported experiences indicated nonlinear recovery. Some domains improved over time, but some remained impaired.
How do these compare to a healthy population?	PwLC scored below controls and normative data on a large portion of tasks, evidence cognitive impairment.

What are the lived experiences of pwLC?	Participants described impact on identity, impact on work and socialisation, and on grief and adaption. Described how memory functioning affected everyday life and sense of self. Participants also reported feeling invalidated by healthcare professionals and the barriers to support they encountered. Private healthcare was often, essential but inaccessible to many, raising participant concerns about equity.

Research Question	**Findings**
Can pwLC store new memories?	PwLC retained the ability to store new information, but many showed impairments in encoding or rehearsal or both, which are key for long term storage. Qualitative data aligned with quantitative results whereby participants reported relying on multiple repetitions and external memory aids.
Are long term memories impacted?	Some participants reported intact LTM, while others described gaps and retrieval difficulties. Participants were able to recall past events in the semi-structured interviews; however, they were described as more difficult to access.

Which specific memory components impaired and intact?	Impaired: STM, verbal, rehearsal, are semantic including name and word finding difficulties and procedural memory. Intact: semantic categorisation, visual memory, LTM and mental time travel.

This research provides evidence of persistent cognitive impairments up to 60 months post Covid-19 infection and further adds existing literature on the long-lasting consequences of Covid-19 by demonstrating that these extend well beyond the acute phase. These impairments are not exclusive to memory but also encompass other areas including reduced daily functioning and quality of life. The longitudinal nature of the research has provided evidence that some memory functions may improve over time, such as verbal recall, while other memory functions such as recognition may remain impaired, which highlights the domain specific trajectory. Furthermore, the contrasts between domains provides evidence that as well as domain difference, the impact of LC on cognition appears to vary between tasks within the same domain.

The longitudinal study in this thesis tracked participants for 24 months. While other longitudinal studies have monitored participants for comparable time frames or longer, such as up to three and a half years (Vallée et al., 2025), up to three years (Cai et al., 2024), up to 24 months (Yeung et al., 2025) and up to 22 months

(Helmsdal et al., 2022), they were not exploring the long-lasting cognitive effects of LC, as described in the introduction. The participants in this study had been living with LC for between 24 and 60 months, the average was 44 months post-acute Covid-19 infection which makes this study, to the best of our knowledge, one of the longest which focused on long-term trajectories in people with more chronic LC.

This thesis applied established models, such as the working memory framework (Baddeley & Hitch, 1974), alongside the identity framework (Oris et al., 2016), the model of Chronic Sorrow (Eakes et al., 1998), and the biopsychosocial framework (Engel, 1977), to a novel patient population, pwLC of working-age. This not only enhances understanding of the cognitive mechanisms likely to be involved in observed impairments but also situates these impairments in the broader context of lived experiences, including around identity reconstruction following chronic illness, and provides a framework to generate and test new hypotheses. This research has highlighted how cognitive changes in pwLC interact with other factors such as fatigue and severity, functional limitations and the concept of self in pwLC.

The thematic analysis provided validation to the quantitative findings and demonstrated how cognitive impairments, fatigue and functional limitations manifest in daily life. These findings highlight not only the importance of capturing lived experiences, but also provide further evidence of the long-lasting impact of LC. Furthermore, the narratives in the thematic analysis highlighted a gap in care and support for pwLC on low income, whereby they could not privately fund treatments, placing them at disadvantage for recovery.

While the implications of this thesis are specific for LC, they may also extend and inform other chronic conditions with overlapping symptom profiles including ME / CFS. The overlap in symptomatology raises further research questions, including whether people with ME / CFS demonstrate the same domain and task specific cognitive impairments, alongside preserved functions in other domains, as discussed in Chapter One. Given the recent genetic study on ME / CFS (DeCodeME, 2025), future research could examine if genetic markers are associated with cognitive impairments in pwLC as this could help to clarify whether there is any shared genetic or inflammatory responses that might directly contribute to cognitive impairments across different post-viral conditions.

Alongside the implications for future research, the findings of this thesis also have implications for cognitive support, overall patient support, and social care for pwLC.

Cognitive Support

The findings suggest that pwLC would benefit from cognitive assessments to identify impairments and which could inform personalised interventions. As discussed in Chapter One, the Montreal Cognitive Assessment (MoCA) has been widely used in LC research (Amalakanti et al, 2021; Del Brutto et al, 2021; Gautam et al, 2022; Piloto et al, 2021; Rass et al, 2021) but this may lack sensitivity to detect subtle cognitive difficulties (Lezak et al., 2012) and identify domain-specific concerns. Furthermore, given the variability between tasks observed within this thesis suggests that assessments such as the MoCA may not be an appropriate tool to detect task specific deficits. The impairments found are not covered in bedside screening tool s like the MoCA. With the use of a sensitive assessment, such as the BMIPB-II, this research has illustrated that some domains are intact in pwLC while others are impaired (Table 32) which basic cognitive screening may not detect. Alongside cognitive assessments, daily functioning assessments could help identity those who may need referrals to social care and could also aid in diagnosis.

The findings also indicate a need for cognitive interventions to support pwLC. The terms cognitive stimulation, cognitive training and cognitive rehabilitation are often used interchangeably (Clare & Woods, 2004) and although they have different applications in terms of settings and clinical groups, they all refer to the implementation of interventions with the intention of enhancing cognitive outcomes. Cognitive training is commonly used to target specific cognitive functions and in populations with memory deficits such as Alzheimer's disease (Farina et al., 2002). Whereas cognitive rehabilitation is often used in conjunction with functional skills training to improve the ability to perform activities of daily living, often with patients with dementia (White et al., 2014). These approaches to training have also been shown to improve outcomes for self-care difficulties, resulting from memory impairments. Given the self-reported functional limitations in pwLC, cognitive rehabilitation approaches when used in conjunction with functional skills training, may improve self-care, which has previously been shown in pwLC (Saxon et al., 2025) and for people living with an acquired brain injury (Cicerone et al., 2019).

Considering the impairments in Story Recall and List Learning within this sample of pwLC, cognitive interventions should aim to focus on and target strategies to improve encoding and retrieval. Interventions such as spaced retrieval (Small & Cochrane, 2020) and errorless learning (Sohlberg et al., 2005) may be of use to pwLC given their effectiveness evidenced with other populations with memory difficulties (Baddeley & Wilson, 1994). These interventions reduce cognitive load and limit interference (Baddeley & Wilson, 1994; Small & Cochrane, 2020; Sohlberg et al., 2005) which would be beneficial to pwLC given, the impairments and impact of fatigue observed within this thesis. Furthermore, although semantic categorisation was not impaired for this sample, research has shown that training on this task, can enhance episodic memory (Miotto et al., 2020) . Working memory training with tasks such as the n-back task (Owen et al., 2005) could help pwLC improve their attention and working capacity.

The impaired processing speed that was observed on the examiner administered task, suggests that intervention targeting this may be appropriate for pwLC. Speed of processing interventions have been shown to increase processing speed regardless of age and education, alongside increase performance in activities of daily living (Ball et al., 2013).

Given that there are some similarities between pwLC and other clinical populations including those with ME / CFS and ABI, particularly with regards to slower processing speed and difficultly in sustaining attention (Huisman et al, 2004), exploring interventions that can successfully improve cognitive performance would be prudent to support for pwLC. The exploration of ways of enhancing neuroplasticity and building cognitive reserve could be beneficial to pwLC. Negative neuroplasticity can lead to low cognitive reserve and cognitive decline (Savarimuthu & Ponniah, 2024). Common factors to increase neuroplasticity include occupation and life experiences (Savarimuthu & Ponniah, 2024), which as addressed within this thesis are reduced for some pwLC. However, reading, an alternative to occupation and life experiences, requires engagement of memory, language and executive function (Savarimuthu & Ponniah, 2024) and may be a suitable, low cognitive fatigue, activity for pwLC that might help increase neuroplasticity. Research has shown neuroplasticity can be developed throughout a lifetime (Kumar et al., 2019; Sorrells et al., 2018). Additionally, as cognitive reserve increases, the resistance and resilience of the brain reserve against cognitive decline or cognitive impairment improves (Savarimuthu & Ponniah, 2024), this could help offer protection of further decline.

Technology based rehabilitation may be beneficial to pwLC. Given the fluctuating nature of symptoms of LC, reduced travel demands and longitudinal progress tracking would be well suited to this population. These platforms would enable pwLC to access rehabilitation from their own homes for more flexibility. Computerised training has been found to be beneficial in improving working memory in other populations, such as with children with attention deficit hyperactivity disorder (ADHD) (Holmes et al., 2009; Klingberg et al., 2005) and patients with stroke (Westerberg et al., 2007). Plasticity-based technology training has been shown to be beneficial in reducing age related cognitive decline (Mahncke et al., 2006). These platforms could be adapted for pwLC to prevent PEM, to help to manage fatigue, and incorporating symptom-tracking to monitor symptom fluctuations.

The use of physical exercise to improve cognitive functioning has been widely researched and found to be beneficial in other populations (Gajewski & Falkenstein, 2016; Ryan & Nolan, 2016) , including improving cognitive functioning in older adults (Angevaren et al., 2008). However, as discussed in the introductory chapter, exercise has also been shown to have detrimental effects to some pwLC (Greenhalgh et al., 2024) and it is debated whether it should be recommended for those with ME / CFS (Petrie & Weinman, 2017) due to symptoms such as POTS and how exertion can induce PEM. Thus, incorporating physical activity in a person's routine should be individualised and recommended cautiously.

Patient Support

The narrative of loss, grief and uncertainty running throughout Chapters Two and Three, highlight how the lived experiences of patients can provide key insights into how it feels to live with LC, and the areas where support is required. The findings can inform practices in patient support services.

Many participants reported lack of recognition of their symptoms and feeling of invalidation. Healthcare education into LC could improve professional awareness of, not only the cognitive symptoms of LC, but also the multidimensional aspect, given its impact on various aspects including quality of life. Training programmes could identity and help pwLC access to specialist support in a timelier manner. Multidisciplinary, personalised approaches are likely to be highly beneficial for pwLC, given the wide range of impairments evident from in the findings of this thesis. A combination of cognitive training, symptom management, strategy training and support for the identity disruptions, would all likely improve outcomes for pwLC. Additionally, given the findings of longitudinal impairments, persistent up to 60 months post-infection, long-term follow-up rather than short-term support alone, should be provided to patients and should include repeated assessments of cognitive impairments and ability to carry out activities of daily living for the most severe and persistent cases.

The impairments evidenced within this thesis highlight the importance of education for pwLC, their families and support networks. Information regarding the nature of cognitive impairments and fluctuating symptoms that may arise, alongside understanding the difference between memory loss and retrieval difficulties, may be useful to increase understanding, reduce anxiety and promote adjustment in the context of expectations regarding recovery. An example of an education leaflet is illustrated in Figure 48.

Figure 48. Long Covid Awareness Leaflet

How to prevent Long Covid

Do not catch Covid-19! To prevent Long Covid, protect yourself and others. Having up to date Covid-19 vaccination status can significantly reduce the risk of severe acute

Covid-19 and hospitalisation, alongside Long Covid.

The use of face masks such as the FFP2 can reduce the risk of contracting the airborne virus.

Good ventilation- open windows, air cleaners & HVAC filters

Management & Treatment

The National Institute for Health and Care Excellence (NICE), alongside the National Health Service (NHS) have developed framework and guidance for clinicians and primary care settings

Multidisciplinary approaches have the best outcomes to ensure all symptoms and presentations of Long Covid are being managed.

Rehabilitation programmes can be helpful where appropriate to use but these should be with caution and discussed with specialist teams such occupational therapists and physiotherapists. Physical exertion should be carefully managed as there is evidence to demonstrate in some cases it has made symptoms and the trajectory of Long Covid worst.

Medications to help reduce and/or alleviate symptoms have been helpful.

5.

Caring for someone with Long Covid

Read to gain further understanding, especially from those who have experience directly.

Active listening & compassion is vital.

Physical support such as personal care, household tasks, running errands & helping organise medical appointments

Raising awareness & advocating. Contributing to scientific research & fundraising to improve resources.

Support Services

Long Covid support, research updates and more **www.LongCovid.org**

C19-YRS- Digital platform, recommended by the NHS, NIHR & NICE.

Visible App-Tracking symptoms for Long Covid and ME/CFS
www.makevisible.com

MIND
www.mind.org.uk

Open Medicine Foundation
https://www.omf.ngo

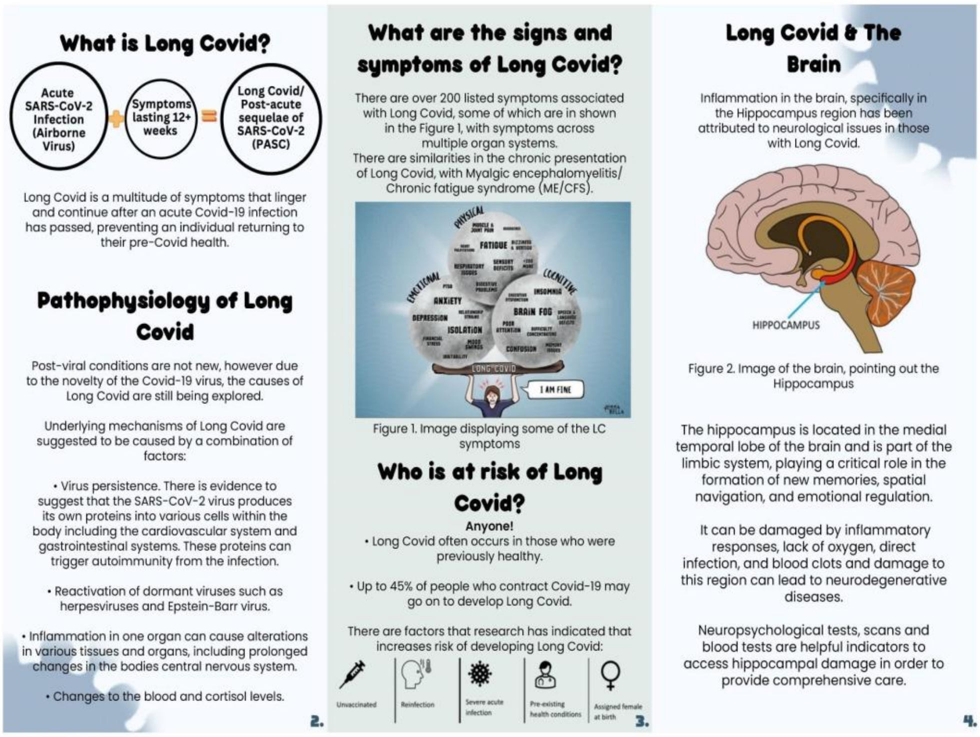
6.

Long Covid

An information flyer for those living with Long Covid, their families/carers & the general population.

Long Covid is affecting at least 65 million individuals worldwide and without clear treatment plans in place this figure is likely to continue rising. Long Covid is a multi-system condition, resulting a large number of the population missing from their everyday lives.

1.



What is Long Covid?

Acute SARS-CoV-2 Infection (Airborne Virus) + Symptoms lasting 12+ weeks = Long Covid/ Post-acute sequelae of SARS-CoV-2 (PASC)

Long Covid is a multitude of symptoms that linger and continue after an acute Covid-19 infection has passed, preventing an individual returning to their pre-Covid health.

Pathophysiology of Long Covid

Post-viral conditions are not new, however due to the novelty of the Covid-19 virus, the causes of Long Covid are still being explored.

Underlying mechanisms of Long Covid are suggested to be caused by a combination of factors:

- Virus persistence. There is evidence to suggest that the SARS-CoV-2 virus produces its own proteins into various cells within the body including the cardiovascular system and gastrointestinal systems. These proteins can trigger autoimmunity from the infection.
- Reactivation of dormant viruses such as herpesviruses and Epstein-Barr virus.
- Inflammation in one organ can cause alterations in various tissues and organs, including prolonged changes in the bodies central nervous system.
- Changes to the blood and cortisol levels.

2.

What are the signs and symptoms of Long Covid?

There are over 200 listed symptoms associated with Long Covid, some of which are in shown in the Figure 1, with symptoms across multiple organ systems.
There are similarities in the chronic presentation of Long Covid, with Myalgic encephalomyelitis/ Chronic fatigue syndrome (ME/CFS).

Figure 1. Image displaying some of the LC symptoms

Who is at risk of Long Covid?

Anyone!

- Long Covid often occurs in those who were previously healthy.
- Up to 45% of people who contract Covid-19 may go on to develop Long Covid.

There are factors that research has indicated that increases risk of developing Long Covid:

Unvaccinated | Reinfection | Severe acute infection | Pre-existing health conditions | Assigned female at birth

3.

Long Covid & The Brain

Inflammation in the brain, specifically in the Hippocampus region has been attributed to neurological issues in those with Long Covid.

Figure 2. Image of the brain, pointing out the Hippocampus

The hippocampus is located in the medial temporal lobe of the brain and is part of the limbic system, playing a critical role in the formation of new memories, spatial navigation, and emotional regulation.

It can be damaged by inflammatory responses, lack of oxygen, direct infection, and blood clots and damage to this region can lead to neurodegenerative diseases.

Neuropsychological tests, scans and blood tests are helpful indicators to access hippocampal damage in order to provide comprehensive care.

4.

Fatigue Management

Considering fatigue was one of the most prevalent symptoms and a predictor of cognitive performance, education should include information and support for patients around managing fatigue, including pacing strategies.

The interactional effects observed in the longitudinal analyses, between fatigue and cognitive performance, provide evidence to suggest that fatigue management is crucial for pwLC, in order to not only reduce its impact on cognitive function, but also improve functioning. Pacing, which can include energy budgeting and prioritising of tasks, can reduce direct symptoms of fatigue and helps to reduce the risk of PEM for those with ME / CFS (Goudsmit et al., 2012) and was found to help reduce fatigue interference in patients with pain (Murphy et al., 2010). Pacing strategies were reported as useful by 30% of participants in the survey responses (Table 10) and emerged in the thematic analysis. Coupled with evidence from those with ME / CFS, these findings indicate that pacing strategies could be a useful tool in the LC intervention toolbox. Furthermore, the use of diaries and activity trackers may help to identify triggers and avoid PEM. The app ‘Visible’ is recommended by NICE, the NHS and the Centers for Disease Control and Prevention (CDC) to support those with chronic illness with pacing (Visible, 2025).

As discussed in the introductory chapter, NICE recommend medical tests to rule out other explanations for fatigue. Pharmacological interventions such as lose-dose Naltrexone (LDN), have been used to reduce fatigue in pwME / CFS (Bolton et al., 2020). While research using LDN for pwLC has shown promising results on lowering the number of symptoms and improving the severity of fatigue and PEM (Bonilla et al., 2023; O'Kelly et al., 2022), further clinical trials are required before LDN can be approved for pwLC.

The present findings provide evidence that LC is a long-lasting condition, continuing to impact fatigue and cognition, and resulting in fluctuating but debilitating symptoms, at least five years post-infection. The nature of these long-lasting effects has a direct impact on daily life for pwLC. A disability is defined as a condition that has long term, ongoing (for at least 12 months) and substantial adverse effect on day-to-day functioning (ACAS, 2024), which was found for the majority of pwLC who participated in these studies, demonstrating that LC aligns with this definition. Recognition of LC as disability, both on a societal and policy level, would enable pwLC to access benefits (e.g. personal independence payments-PIP) and more inclusive social support, as well as occupational health support or vocational rehabilitation to support to return to work. While LC is not universally recognised as a disability, in the UK its acknowledged under the Equality Act 2010, as evidenced in several employment tribunal cases within the United Kingdom (*Long COVID Recognised as a Disability*, n.d.; Starling, 2022) .

Qualitative findings highlighted barriers in accessing medical support, with financial privilege determining ability to access treatment. If LC was consistently classified as a disability, as per the ACAS definition, access to support could be more equitable. At present, in the UK, evidencing the need for financial support includes obtaining a letter from a GP, LC clinic or evidence of receiving active treatment (*Scope UK*, n.d.). Furthermore, recognition of LC as a chronic condition, may help to reduce the stigma and manage expectation of others, that were discussed in the qualitative data.

Social Care

The findings suggest that pwLC could benefit from both social care support, but also broader social and community-based support to mitigate the impact of their memory impairments and other LC symptoms. Difficulties with instrumental daily functioning, including cooking, self- care and managing the household, were frequently expressed by participants.. Additionally, pwLC reported experiencing safety risks due to cognitive difficulties, including home security and being disoriented while traveling, which offers further evidence that social care support may be beneficial. As discussed herein, these impairments are having an impact on pwLC's sense of self, reducing their independence and therefore increasing reliance on others for support. Local authorities should assess needs of severe patients with LC, considering the Care Act 2014 in UK. Some pwLC may benefit from support with cooking and personal care, alongside support for booking and keeping appointments.

Social and community support can help to reduce isolation, improved mental health and enhance quality of life (S. Cohen & Wills, 1985; Holt-Lunstad et al., 2010). Social isolation has been associated with poorer health outcomes (Holt-Lunstad et al., 2010) and therefore highlights the importance of socialisation and community engagement for those with long term conditions. In the United Kingdom, social prescribing is a way of linking patients with their local communities to reduce isolation (Bickerdike et al., 2017). As well as improving patients' wellbeing, it can also reduce workloads on healthcare professionals and ensures people can get adequate support in the community (Drinkwater et al., 2019).Integrating formal social care and community support create a holistic approach to rehabilitation which may benefit pwLC. Social prescribing and community support may help pwLC to rebuild community integration, increase confidence and reduce the psychological impact of LC.

Functional Interventions

The qualitative findings align with previous research on the effects of personal identity changes and chronic grief in pwLC (Burton et al., 2022; Kingstone et al., 2020). Psychological interventions such as acceptance and commitment therapy (ACT) and cognitive behaviour therapy (CBT), adapted to meet the needs of pwLC, may support adjustment to the persistent but fluctuating symptoms and functional limitations they experience. CBT has been used in patients with chronic fatigue, however the long term benefits of this remain unclear (Blease, 2016). ACT has been used for patients with long term conditions and there is evidence to suggest improvement of quality of life and symptom control (Graham et al., 2016). While functional interventions for pwLC are still developing, psychological support and self-management strategies have reported improvements with quality of life and symptom management (Harenwall et al, 2021). Participants discussed how 'spoonie' networks, speaking to others with chronic illnesses, have helped them throughout their LC journey, highlighting the benefit on connecting with others in similar circumstances.

The use of digital and assistive technology, as previously discussed, could also help to support individuals to regain some independence, this functional limitation caused distress to participants, therefore any tools that might reduce the impact of LC on independence, could be that would be highly beneficial. Promotion of management (health and time) applications with reminders, such as Google calendars or smart assistants such as Alexa, could reduce memory lapses and empower pwLC to feel more autonomous and independent. The use of other external memory aids such as journals could be a useful tool to compensate for reduced recall and also increase independence (Kinsella et al., 2009) where information is required, without needing to rely on others.

Workplace Support

This thesis has provided evidence that the combination of cognitive impairments, fatigue and fluctuating symptoms may present barriers to sustainable employment for pwLC. As discussed in the introductory chapter, workplace support for pwLC is currently limited and many pwLC have reported unfavourable treatment while at work (Kromydas et al., 2023). The findings within suggest that employers should consider the LC profile of employees. Fluctuating symptoms, cognitive burden, fatigue and the need for pacing, could be managed in the workplace by promoting flexible working hours, regular breaks and the use of written communication to support employees who may be experiencing memory lapses or slowed information processing.

Furthermore, employer education on the fluctuating and sometimes invisible nature of LC symptoms could help reduce stigma and provide empathetic responses in for pwLC in employment.

Strengths and Limitations

Strengths

The first strength of this thesis is the use of a mixed methods design, which integrated the quantitative cognitive data with qualitative lived experience to provide a more nuanced picture on what it is like to live with LC. The themes that emerged during the analyses of the open-ended survey responses and the semi-structured interviews, provides further evidence of the longitudinal impact LC is having, alongside the assessment data.

The online delivery format used in the assessments, enabled participation inclusion from different regions and countries. This ensured participants were not just recruited from one area within the researcher’s proximity. This is evidenced by the participation of people from 10 different countries at Assessment One. The format also increased the recruitment of participants with LC who otherwise may have been limited by their ability to travel to participate in the research, as the challenges revealed within the thematic analyses demonstrate. The choice to complete the interviews online via Zoom also maximised geographical spread was beneficial as it enabled a larger reach of participants. Additionally, the booking system used allowed flexibility for participants to select the slot that was suited to them and their commitments, rather than being limited in availability which may have hindered participant recruitment or narrative detail (e.g., due to fatigue).

Despite being predominately an online study, data were collected via use of both self-guided tasks and examiner administered cognitive tests. The inclusion of self guided tasks allowed participants to complete tasks at their own pace, which, as covered within the results of the thematic analyses and the self-reported management techniques in Table 10, was important to reduce participant burden especially for those experiencing fatigue or fluctuating symptoms, which were heavily reported. In contrast, the examiner administered assessment provided standardised administration and participant support, enhancing the reliability and validity of the results. Guo et al. (2022) listed a limitation of their research as being without researcher oversight to account for any data quality issues. This research has been able to address this with at least within the examiner administered cognitive tests.

Furthermore, the longitudinal design allowed for cognitive and functional changes to be explored over time rather than at a single assessment point. Longitudinal follow up with pwLC has been recommended in previous literature (Graham et al., 2021; Hampshire et al., 2021) as it can aid understanding of symptom progression. By tracking performance and symptom trajectory over time, there was the ability for conclusions to be formed on the limited evidence of change or recovery over 24 months, as well as comparing performance between assessments. This applied to not only the cognitive tasks, but also to symptoms and measures of function.

Additionally, this design allowed for participants performance to be assessed on presentation of the day of assessment/survey rather than relying on retrospective self-reporting, this aligns with LC research recommendations (Loft et al., 2022).

The use of semi-structured interviews allowed the researcher to delve more deeply into responses during the interview and to probe further into responses if required, compared to the online survey responses analysed in Chapter Two. The use of semi-structured interviews to explore memory difficulties and the extent to which they impact everyday life has brought the voices of those with lived experiences to the forefront. The flexible approach used to analyse the data (Braun & Clarke, 2021), provided a framework to develop themes based on the lived perspectives of pwLC. The analyses can be created and constructed in two ways; researcher provoked data and naturally occurring data (Silverman, 2024). This research used researcher provoked data with predesigned interview questions. Literature reviews prior to data collection gave some insight into lived experiences for pwLC but the data collected during the study allowed for codes and themes to be constructed. Complete, open coding (Flick, 2013) was used throughout the process to ensure all data was thoroughly examined. Furthermore, most of the questions in the semi-structured interview, with a few exceptions, focused on the present day during the interview rather than relying on retrospective memory, which has been pointed out as a limitation in other qualitative research (Loft et al., 2022).

While supportive technology such as NVivo offers benefits for qualitative analyses including supporting data management and retrieval that help support the analyses

(Maher et al., 2018), it also has some constraints such as limited data interaction in comparison to manually coding. While manual methods of thematic analysis can be more time consuming, these were used in this thesis which allowed deep and meaningful immersion and interaction with the data. This process helped to increase the researcher's skills of critical thinking and enabled links in the data to merge and ensure the voices of the participants remained at the heart of the analyses, while providing a coherent narrative.

Limitations

Despite the strengths of these studies, limitations should be acknowledged. The data were derived from voluntary survey responses for the thematic analysis, which introduced the potential for self-selection bias. Individuals who have had particularly negative or distressing experiences with LC may have been more motivated to share their stories, while those with more neutral or positive trajectories or those who were too fatigued to answer, may have chosen not to provide a response to the open ended survey question. Furthermore, these analyses may not have fully captured the perspectives of participants experiencing profound fatigue or cognitive burden, who may have been too exhausted to complete open-ended responses which appeared at the end of the survey. As a result, the dataset may disproportionately reflect experiences of struggles and frustration, thereby underrepresenting voices of resilience and successful symptom management or recovery. As the attrition figure shows, some people who had previously taken part in the research, had informed the researcher they had returned to work.

Although the surveys provided space for open-ended responses, the lack of researcher interaction may have limited opportunities for clarification of the participants' narratives. However, online qualitative data collection has become popular since it became more readily accessible and affordable and enables contact with hard to reach populations (Wilkerson et al., 2014) and it is now used to generate valuable research data, including health-related research, as it allows for broader participation, particularly from individuals who may face geographical or physical barriers to in-person research and guidance for researchers keen to use this method has been developed (Wilkerson et al., 2014). Collection of online qualitative data via surveys, has been widely used during and since the Covid-19 pandemic (Torrentira, 2020)

It is also important to acknowledge potential researcher biases while interpreting the open-ended responses to the survey and creating themes from the semi-structured interviews. The process of qualitative analyses, particularly thematic analysis, has the potential for subjectivity and personal experiences to influence how the data are interpreted. However, a strength of thematic analyses is that the researcher can take an active role in identifying themes and purposely select themes of interest, compared to discourse analysis whereby themes 'emerge' naturally from the data, minimising the interpretation of the researcher (Singer & Hunter, 1999). A minimalist approach may offer clarity, reducing the risk of over-interpretation. However, a maximising approach was deemed appropriate to ensure that the richness and complexity of participants experiences were fully captured.

Reflexivity was practised throughout the analyses to ensure that assumptions and emerging thoughts during each stage of the analysis were explored. This felt especially important given the sensitive nature of LC and the fact the researcher has spent significant amount of time with pwLC, which could lead to the emergence of illusory themes. As an example, there was expectation that participants may report an increase in resilience over time in the open-ended responses, particularly by Assessment Three as some LC participants had expressed some resilience during time spent with the researcher for data collection on Zoom. This may have inadvertently led to paying more attention to data reflecting adaptation or coping. However, reflexivity was used to separate assumptions from what the responses expressed to refine themes. Although this does not eliminate researcher biases, it improves transparency.

As the researcher had previously completed thematic analyses of survey responses of pwLC (Chapter Three), they were mindful to approach the data set in Chapter Four, with no preconceived ideas and ensure that the analyses of the interview transcripts focused solely on what the participants were saying, to capture their raw lived experiences objectively, not expectations of what they might report to ensure this analysis represents the voices of pwLC. To reduce the risk of bias, the researcher was mindful to document thoughts, the patterns in the data and what these accounts could be illustrating throughout the thematic analyses. These reflective notes allowed for regularly checking of whether interpretations were grounded in the data, rather than shaped by preconceived ideas. My positionality has brought both strengths and limitations to this study. A strength is the professional rapport that I have built with the LC community over the last three years prior to the data collection for this study. This enabled trust to be built and in turn made the participants feel more at ease during the data collection, which may have contributed to the level of details that were shared during the interviews. However, this also may have inadvertently contributed to researcher bias. Additionally, although the scoring procedure (Levine et al., 2002) was adhered to for the adapted autobiographical interview responses, inter-rater reliability was not established which may introduce biases in how the responses were coded into internal and external categories, thus potentially affecting the overall tallies and analyses. This also was the case for the coding of the codes and themes. However, the same scorer and scoring method was used across transcripts to provide consistency and this was rechecked numerous times throughout the coding process.

There are also some difficulties to acknowledge during the coding process itself, due to the amount of data collected. There appeared to be some overlap between themes as some of the accounts provided were so rich but multidimensional. As the results section was divided between specific concerns and themes, I was conscious that I did not want the reflections to lose the context in which they were shared. Due to this the coding felt difficult at times as I wanted to ensure I could present the results in a structured way to facilitate comprehension and maintain a narrative. As previously mentioned, the regular reflections throughout helped with these challenges.

Another limitation regards the sampling of the participants who took part in this research. The sample sizes in each study were relatively small (Assessment One: *N*

= 68, Assessment Two; *N* = 46, Assessment Three; *N* = 39, thematic analysis at three different times; *N*= 63, *N* = 22, *N* = 22 and Semi-Structured interviews: *N* = 26) and may not have been representative of the LC population. However, within the qualitative research, the survey responses and semi-structured interviews, the aim is not to generalise but to explore the lived experiences and the participants. The data was for the thematic analysis did reflect a working age sample of pwLC which was the target population for this thesis.

Attrition in longitudinal studies is common, particularly within chronic illness research where ongoing symptoms may impact participants' ability to remain engaged (Meyerowitz-Katz et al., 2020). Although attrition can hinder data analyses to detect longitudinal changes, Linear Mixed Models were used to account for missing data in cognitive performance and functional measures. Although 14 participants did not respond to the follow up email for Assessment Two, the other reasons for participant drop out were illustrated in Figure 9 and included being too unwell as well as recovering or changes in life circumstances which suggested that both health and practical issues influence participant retention. At Assessment Three, three participants had returned to work, one was recovered, two gave no response and one was not well enough to participate at the time of data collection. While four participants reported improvements such as returning to work or recovery, in contrast another participant continued to experience ill health. This again demonstrates that there a various reason for retention.

Additionally, participants for each study self-selected to take part via recruitment adverts, the majority of which were from LC social media accounts. This may have excluded participants who do not have access to social media, the internet, or those who may have been too unwell to use those platforms. Furthermore, although information on factors such as vaccination status, reinfection history and variants of Covid-19 was collected, these variables were not explored analytically but they could affect symptom patterns and trajectory. To account for these limitations, future research should consider larger sample sizes, recruitment of participants in different ways to achieve more inclusivity and diversity, and investigate the variables not explored in this study, such as reinfection history and its impact on cognitive function over time.

The same control groups were used for comparisons at different time points, which may limit understanding of how natural change of over time differs between pwLC and healthy controls. Additionally, the control groups were not matched with pwLC on the number of years of education. This may have affected the results and has been a limitation in previous LC research, which found had differing ages of education between pwLC and controls (Yeung et al., 2025). Despite this potential confound, it is unlikely that this factor alone would have impacted the conclusions drawn for pwLC. Future research should be more stringent, potentially using matching techniques such as propensity scores, to ensure groups are closely matched and that longitudinal data is collected in all samples, rather than using data from the same time point for controls for comparisons over time with pwLC.

Although the online format of the data collection was a strength, it does also present a limitation. Specifically, the variation in how the BMIPB-II was administered may have influenced the findings. While pwLC completed the assessments with an examiner virtually, the normative data that were used for comparisons were collected via face-to-face administration. Additionally in the present study participants were presented with the test materials via an audio recording, whereas in the standardised sample the test materials were read out by the examiner within each session. This procedural difference may have impacted performance. While healthy controls who completed the assessment in the same virtual format as pwLC, performed better than pwLC, they performed poorer than the normative sample. This suggests that the two modifications to the mode of administration may have contributed to the findings, but they are not the only factor at play as they do not fully account for the differences observed between groups.

A further potential limitation is the overrepresentation of women in the LC sample in comparison to the other samples. Although women are more at risk of LC (Fernández-de-las-Peñas et al., 2022), the imbalance in the sample sizes limits the generalisability of findings to the broader LC population. Cognitive impairments and symptom trajectory may vary between sexes, thus the predominance of women in the samples may not consider sex differences. However, the sex imbalance observed is consistent with existing literature in LC research (Davis et al., 2021; Velichkovsky et al., 2023) and given that LC is more prevalent in women than men as discussed during the introduction, this is not necessarily a limitation. However, including acute Covid-19 severity and LC severity in the LMM allowed for inclusion of all the data available.

Additionally, the significant difference in years of education between the LC group and control groups may also have impacted the findings. Research has confirmed that increased years in education correlate with higher cognitive abilities, thus better performance (Opdebeeck et al., 2016). Therefore, the differences between pwLC and controls may reflect educational advantages in the control groups, rather than the direct impact of LC. However, the level in education in pwLC, which ranged from 10 to 24 years is relatively high and therefore does not indicate lower pre-morbid function in this group.

The absence of direct measures of pre-morbid cognitive functioning is a common limitation for Covid-19 research (Graham et al., 2021). As a result, the observed cognitive difficulties in pwLC cannot be definitively attributed to the LC. Without earlier cognitive assessments or prior evidence of performance, it is possible that some impairments may have been present pre-morbidly. However, the Word Categorisation task that was included may be used as a proxy measure of premorbid functioning and cognitive abilities. Semantic memory is stable over time and relatively resistant to neurological disruption. This has been demonstrated in hippocampal damaged patients such as H.M (Squire et al, 2002) as well as in individuals at increased risk for Alzheimer’s disease who perform well on semantic tasks (Woodard et al, 2009). This task assessed both accuracy and response time across three assessments. Out of six results, three accuracy and three speed scores, only one measure (accuracy at Assessment Two) showed a significant difference between pwLC and control participants which suggests that semantic categorisation abilities remain intact in pwLC. The preserved semantic categorisation performance in pwLC participants provides some support for the interpretation that other cognitive deficits observed within the results likely reflect the effects of LC rather than of pre-morbid impairments.

This thesis has presented details on how LC affects cognition, fatigue, quality of life and daily functioning, however no objective assessments of independence were carried out, and the data relating to quality of life, fatigue and daily limitations were all self-reported in questionnaires which may have led to some bias in the participants' reporting.

The results presented throughout this thesis used behavioural and self-reported data only, which can be helpful for interpretations and suggesting interventions, however this thesis did not collect any data for direct evidence of brain areas affected. Although there was suggesting the potential involvement of the hippocampus in this sample, no neuroimaging data were collected. Nevertheless, the consistency between behavioural data herein, with evidence from published neuroimaging studies, strengthens the plausibility of this interpretation and guides future research directions.

The item recognition task used within this thesis provided some insights into memory performance in pwLC, however as mentioned in Chapter Two, it has some methodological limitations which should be acknowledged. Firstly, the hit and false alarm rates reflect decision processes as well as memory strength, meaning that performance may be influenced by response bias in addition to discrimination ability. For example, participants with poorer discrimination between old items from new items may adopt a more liberal response which would result in both elevated hit rates and elevated false alarm rates. Hit/ false alarm measures do not provide a pure outcome of memory strength and discrimination measures uncontaminated by bias are preferable (Brady et al., 2023). This discrimination and bias may be particularly relevant in pwLC, where fatigue and reduced memory confidence may shift their decision independently of their memory ability.

Furthermore, this old / new recognition can be supported by familiarity based processes, whereby the participants respond accurately without retrieving the event specific contextual detail (Yonelinas et al., 2002). This can result in recognition performance underestimating everyday difficulties that rely on retrieval and recollection, potentially obscuring deficits. Another criticism of this method is that recognition judgements may involve metacognitive and counterfactual reasoning, raising questions regarding the construct validity of using old/ new paradigms when trying to capture episodic memory integrity (Brady et al., 2023).

Future research should therefore consider alternative approaches to measure encoding, recollection and decision components separately. The remember/ know paradigm provides better output for episodic versus non episodic retrieval which can improve interpretability (Yonelinas et al., 2002). Additionally, recognition memory performance should be modelled using signal detection theory such as the area under the receiver operating characteristic (ROC) curve as first suggested by Norman and Wickelgren (1965), rather than the measure of hits minus false alarms (Brady et al., 2023). These approaches would provide a more precise assessment of memory processes in pwLC.

This thesis contributes to the growing understanding of the cognitive difficulties and lived experiences of pwLC. It has demonstrated with evidence from quantitative and qualitative data, that memory and cognitive difficulties are reflected in everyday functioning. The integrated findings collected longitudinally emphasise the importance of using sensitive measures of cognitive performance and long-term follow-ups as part of the personalised care and treatment offered to pwLC. LC education, workplace support and social care will have an essential role in addressing safety concerns, increasing independence and reducing health inequalities. These findings may also have implications for practice beyond supporting individuals with LC. The findings within this thesis offers insights into cognitive assessments and long-term support which may be applicable for individuals with different chronic conditions. The mixed method, longitudinal approach throughout this thesis has captured the complexity of LC and demonstrated the impact of LC upon memory, identity, functional outcomes and much more. Overall, this thesis highlights the need to recognise, validate, assess and adequately support the cognitive and lived experiences of pwLC.

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