# Exploring Clinicians' Experiences of Implementing Assistive Technology for Cognition in Neurorehabilitation: Insights and Challenges

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A thesis submitted in partial fulfilment of the requirements of the University of Essex for the degree of Professional Doctorate in Clinical Psychology

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University of Essex

February 2025

# Acknowledgements

I would first like to thank my thesis supervisor, Professor Andrew Bateman, for his continued support, enthusiasm, guidance, and endurance throughout this project. Without him, this thesis would not have been possible.

I am also grateful for Neumind's support. Thank you for your time and contributions to this area of research. I look forward to following your work closely in the future.

Thank you Ailish and Katie, my fellow psychologists, whose sanity and insanity have matched my own across our doctoral training journeys. You have both enriched and supported my journey in ways I’m sure no one else could have.

Over the years, countless friends have offered comfort, interest, and escapism and supported me in completing this research. In particular, thank you to Conor, Matt, and Sam for not getting really sick of me.

And finally, thank you to my mother for checking in on me and offering unwavering support.

# Abstract

Traumatic brain injury (TBI) is a significant public health concern, frequently leading to long-term cognitive, emotional, and functional impairments. Despite growing recognition of the need for intense and long-term neurorehabilitation, access to ongoing support remains inconsistent, particularly within the United Kingdom. Assistive technology for cognition (ATC) has been identified as a potential means of addressing these challenges, offering tools that can support memory, executive functioning, and engagement in activities of daily living. However, while ATC's potential is broadly acknowledged, its integration into clinical practice remains diffuse, and the factors mediating its successful implementation are poorly understood.

This thesis examines the role of ATC in neurorehabilitation, with a focus on smartphone-based interventions. A systematic review synthesises existing research on the efficacy of smartphones in supporting memory and executive function for individuals with TBI. Given the heterogeneity of the literature, a narrative synthesis was conducted, evaluating the strengths and limitations of ATC. Evidence for smartphone use in supporting cognition, primarily through the use of electronic calendar functions, was found. Variability in training and inconsistencies in the methodologies of reviewed studies are discussed, further supporting the potential of smartphones as platforms with ATCs. However, more high-quality research is required to inform clinicians and policymakers.

Following this, a qualitative study explores how clinicians working in neurorehabilitation, experienced implementing ATC interventions. Semi-structured interviews were conducted with twelve professionals from various neurorehabilitation settings and disciplines. A reflexive thematic analysis was undertaken guided by Braun and Clarke's (2020) six-phase reflexive approach, identifying five overarching themes: 1) Technology is Diffuse, 2) Make it

Unique (or don't Bother), 3) Context Matters, 4) Professionals Bring Themselves, and 5) The Person Beyond the Injury.

Findings indicate that while ATCs have clear utility, their effectiveness is mediated by training and long-term support, MDT collaboration, and accessibility. It also offers novel insight into an important relational component between the therapist and client that has largely not been addressed in ATC research. The research highlights the need for greater guidance for clinicians, considerations of accessibility, and further evaluation of ATC interventions across clinical settings. Implications for clinical psychology, healthcare services, and future research are discussed. This thesis contributes to research and practice by identifying strategies that clinicians and services can adopt to facilitate the successful implementation of ATC's, while also emphasising the importance of inclusive, person-centred approaches within neurorehabilitation.

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# 1. Chapter One- Introduction

Brain injury has been described as the "silent epidemic" given its significant and pervasive effects, which are under recognised, enduring, and associated with poorer life outcomes following injury (Coburn, 1999). The brain does have the ability to reroute and compensate for some damage, but to maximise recovery of functions and skills, focused rehabilitation is critical (Cicerone et al., 2011). Indeed, with sufficient rehabilitation outcomes and quality of life can be significantly improved for survivors (Eghbali et al., 2020). Unfortunately, global and United Kingdom (UK) investment in services and research has not met the demand for adequate long-term rehabilitation, and as such, there is a discernible shortfall in rehabilitation services. Consequently, many survivors are discharged without adequate access to acute or long-term rehabilitation support (Headway, 2024).

Recovery from brain injury is uniquely complex, given that the initial injury damages brain cells and disrupts neural pathways, which can affect a person in multifaceted ways, impacting cognitive, physical and emotional functioning (Gordon et al., 2006). As such, each brain injury is unique in its pattern of physical injury in the brain, but also how it intersects with the survivor's premorbid functioning, social roles, mental health, and family and social systems around them. Neurorehabilitation must be tailored to the ubiquitous nature of brain injury to maximise positive outcomes. Additionally, the cost-effectiveness of neurorehabilitation has been well established. It has been highlighted as one of the most cost-effective interventions the National Healthcare Service (NHS) provides (The All Party Parliamentary Group on Acquired Brain Injury Report, 2018). However, globally, and specifically in the UK, neurorehabilitation provisions across inpatient and community services are variable. There are enormous human and societal costs as a consequence of traumatic brain injury (TBI), estimated to cost Europe €33 billion (Olesen et al., 2012).

One possible area that may support survivors, caregivers, families, and clinicians is technology. Technologies such as robots, virtual reality, brain stimulation and biofeedback have already been used to augment traditional neurorehabilitation pathways (Zanatta et al., 2022). One such area that appears to hold great potential to support neurorehabilitation is assistive technology for cognition (ATC). Historically, people have used cognitive aids such as notebooks, diaries, and calculators to extend cognitive functioning. The rapid development of technology over the last century has created cost-effective and capable multifunctional tools which are now ubiquitous in everyday life. The utilisation of smartphones, in particular, has rapidly grown and may be a cost-effective aid in supporting survivors with acquired brain injury (ABI) with cognitive deficits.

The following chapter will review the current state of brain injury care and outcomes within the UK and consider the role of ATC in neurorehabilitation.

## 1.1. What is brain injury?

It is useful to clarify some of the language used within the brain injury rehabilitation literature. There have been inconsistencies with definitions and the usage of terms such as "head injury," making discussion of the literature indeterminate. Within the literature, brain injury is often described using two terms: acquired brain injury (ABI) and Traumatic Brain Injury (TBI).

ABI serves as a comprehensive framework that encompasses both TBI and Non-Traumatic Brain Injury, resulting in a multitude of cognitive and behavioural deficits that significantly impact daily life (Goldman et al., 2022). This umbrella term includes traumatic incidents like head injuries from accidents, strokes, cardiovascular events, and illnesses such as brain tumours.

TBI is characterised as being caused by an external physical force, such as a blow to the head from a fall, vehicle accident or so forth. TBI stands as a focal concern within brain injury and has been described as the "silent epidemic" due to its wide-reaching global impact on disability rates (Coburn, 1992). Diagnosis of TBI is multifaceted and relies on numerous indicators such as duration of loss of consciousness, post-traumatic amnesia (PTA), Glasgow Coma Scale (GCS) scores, and reported symptoms (Wang et al., 2018). Of all of the common neurological disorders, TBI has the highest incidence (Mass et al., 2022).

This thesis will predominantly focus on TBI; however, where more general research is discussed, the terminology of ABI will be used where appropriate.

### 1.1.1. Brain injury in the UK.

Acquired and traumatic brain injuries are a growing public health crisis in the United Kingdom. Hospital admissions for brain injuries rose 12% from 2005-2006 to 2019-2020, totalling over 356,000 annually or around 1,000 per day (Headway, 2024). Stroke, one of the leading causes of brain injury, increased by 14% over the measured timeframe to over 137,000 admissions in 2019-2020. Reviews have concluded that general trends are staying the same in regard to incidences of brain injury but that the causes are changing; in developed countries, falls are the leading cause of TBI at 42.4% (Nguyen et al., 2016). Indeed, this trend appears in both the UK and Europe that; car accidents are causing fewer TBIs but is trending more towards falls being the leading cause. Indeed, during the Coronavirus-19 (COVID-19) pandemic referrals for surgery and admissions following TBI decreased significantly, attributed to lower vehicle traffic and patient avoidance of healthcare services (Jayakumar et al., 2020).

The economic impacts of brain injuries in the UK are massive, costing an estimated £15 billion every year when factoring in health and social care costs, lost productivity, and premature death costs (Centre for Mental Health, 2016). Nevertheless, this cost could likely be reduced if survivors were provided holistic and comprehensive neurorehabilitation and support in the community. However, the majority of head injuries are thought not to attend trauma care (Seabury et al., 2018). Survivors not receiving care for TBI is of particular concern. Lack of treatment at the earliest instance and specialist rehabilitation risks neurological deterioration and increased morbidity and mortality, which has personal and economic consequences, especially given that highly specialist rehabilitation has consistently been indicated as highly cost-efficient for patients with TBI with lifetime savings in care costs of £679,776 per patient in the UK (Turner-Stoke et al., 2019).

## 1.2. Demographics of TBI

### 1.2.1. Age

TBI can occur at any age. However, the incidence of brain injury varies across different age groups. The very elderly, or very young, face an increased risk of TBI, with the highest rates of injury reported among adults over 75 years of age (Thompson et al., 2006). Aging is associated with more comorbid conditions, resulting in a greater need for assistance with daily living, both of which are associated with greater risk of falls, which are the most common cause of brain injury in elderly populations (Hawley et al., 2017). In children, the main causes of TBI are falls and car accidents. However, this varies significantly across populations and countries, with trauma, non-accidental trauma, and sport-related injuries also accounting for significant numbers of injuries (Dewan et al., 2016). This range may be moderated by age within paediatric populations; in children aged 0-4 years old, the majority of head injuries are caused by falls, and in older children, the most common cause is car injuries.

However, there are many inaccuracies within reported TBI data, and it is generally agreed that many brain injuries are unaccounted for, given many people with head injuries do not attend hospital or seek medical attention (Taylor, 2017). One United States (US) population-based survey of children and adults found 25% of respondents who experienced a head injury with a loss of consciousness did not seek medical attention (Setnik & Bazarian, 2007). These statistics present the scale of challenges for health and social care systems. Longitudinal studies of adults who have survived hospitalisation for TBI estimate long-term disability amongst nearly 40% of survivors (Selassie et al., 2008). The long-term impairment and disability burden amongst children who have experienced TBI is unclear, but evidence suggests it is significant, with one estimate of more than 60% of children with moderate-to-severe TBI experiencing a disability (Rivara et al., 2012).

Amongst intersecting with the aetiology of TBI, age is also a significant factor in the recovery following brain injury. Compared to working age adults older adults with TBI do experience higher morbidity and mortality and slower recovery trajectories, with worse functional, cognitive, and psychosocial outcomes post-injury (Mosenthal et al., 2004; Ramanathan et al., 2012). Injury mechanisms, patient characteristics, and the biological sequel of TBI among older adults are distinct from those of younger individuals and, as such, require a unique approach to clinical management and research (Gardner et al., 2018).

### 1.2.2. Gender

Gender intersects with the aetiology and recovery from brain injury, but the literature describes a complex and contradictory picture. For example, a meta-analysis of sex differences in TBI identified within studies assessed, outcomes for women were worse in mild-moderate TBI (60%), but across moderate-severe TBI, outcomes for women were better (66%) (Gupte et al., 2019). Many studies have indicated that male patients are more likely to present with brain injury, and it has been estimated that men account for 1.5 times more hospital admissions than women (Ma et al., 2019). Furthermore, common causes of brain injury, such as stroke, are more likely to be elderly and male and therefore, rehabilitation and support groups reflect this, putting female patients (particularly if younger) at a disadvantage. In regards to recovery, women also generally report worse 6-month outcomes, whereas outcomes in men appear to be mediated by TBI severity and age (Mikolić et al., 2021). However, women are reported to have a lower mortality rate compared to men after head injury, and in more severe TBI more often better outcomes are reported in female patients (Mollayeva & Colantonio, 2019).

There is a complex picture of how biological sex affects brain injury outcomes, which fits with the broader consensus on how biological sex influences disease risk, progression and outcomes. This has been attributed partially to genetic, cellular, and physiological mechanisms but should also be viewed in light of gender discrimination in mental and physical health services that occurs worldwide (Madell & Hayward, 2019). For example, a meta-analysis observed that female patients with TBI reported a higher number of trauma symptoms compared to male patients (Farace & Alves, 2000).

It is beyond the scope of this section to fully delve into the relationship between biological sex and TBI, but the complexities reflect a gap in global knowledge about the relationship between sex and gender and rehabilitation and the aetiology of brain injury. Many issues, such as lack of referrals and women's disproportionate global caregiving burden, can be considered as contributing to these differences. Research has revealed that women both provide more care to and receive less care from partners who are men, in part because women face more societal pressure to provide care, live longer than men, have adverse health events that require rehabilitation at an older age, and tend to be younger than their partners (Ott et al., 2022). Therefore, there is a need for research and medical and health systems to take person-centred and gender-responsive care into account, including roles, social structures, and how they intersect with the person's lived experiences, particularly in diverse contexts. It should also be noted that there is a general absence of data on intersex or transgender people and TBI which also further highlights the need for a greater understanding of individual characteristics and TBI.

### 1.2.3. Socioeconomic status

Socioeconomic status (SES) intersects with the incidence of being affected by TBI, as well as the risk and long-term outcomes following injury. Lower SES has been correlated with a higher incidence of brain injury in both paediatric and adult populations (Friger et al., 2018). This relationship may be due to occupational hazards, lack of resources, and reduced access to health education associated with lower SES populations. Indeed, high-risk occupations associated with lower SES have disproportionate rates of head trauma within the profession, such as construction workers, agricultural labourers, and military personnel (Kelly et al., 2021). Indeed, the mechanism of trauma also differs based on SES, and the lower the SES, the more likely the injury is to have been caused by assault or firearms, in comparison to higher SES (Kelly et al., 2021).

### 1.2.4. Race

Health inequalities affecting racial and ethnic minorities are well-documented across healthcare outcomes, both in the UK and globally. The COVID-19 pandemic is a recent and visible demonstration of these disparities, with black and Asian populations disproportionately affected (Jones, 2021). Considering how race intersects with TBI is particularly relevant, as disparities in outcomes are already compounded by factors such as socioeconomic status (SES), access to healthcare, as well as systemic racism, which can influence every stage of the care pathway. For instance, insurance status, injury mechanisms, time to surgical intervention, and access to post-acute rehabilitation all intersect with racial and ethnic disparities in TBI outcomes (Richie et al., 2021).

Research highlights significant disparities in TBI incidence and outcomes along racial lines. Studies indicate that Black populations experience higher rates of TBI than expected and are less likely than White populations to receive rehabilitation or post-acute care (Brenner et al., 2020). Furthermore, institutional biases in the healthcare system mean that white patients are more likely to be discharged to further care, while patients of colour (POC) are disproportionately left without adequate support. Omar et al. (2024) critically examined these disparities through the lens of Critical Race Theory (CRT), identifying systemic racism in TBI research as a driving factor. They highlighted four key mechanisms through which racism is perpetuated in the literature: colour-blind ideologies, meritocratic myths, deficit perspectives, and the normalisation of whiteness as a property that confers privilege.

Racism in TBI care and research is often institutionalised, with disparities embedded in seemingly neutral practices. For example, not acknowledging and discussing race in health research risks obscuring the structural and social conditions that shape health disparities. Equally, taking a deficit approach risks pathologising minority populations, presenting them as inherently "at risk" rather than critically examining the social and systemic factors at play. These narratives collectively reinforce inequities in access to care, quality of rehabilitation, and long-term outcomes (Omar et al., 2024).

In light of social justice movements such as Black Lives Matter and clinical psychology's more recent "decolonisation" of the profession, it is important to adopt an anti-racist approach to addressing TBI disparities. This involves recognising how "whiteness" has shaped psychology and health systems. By acknowledging these systemic issues, this thesis aims to contribute to an inclusive approach to TBI and its outcomes. It seeks to embrace the recommendations of CRT writers like Omar et al. (2024), striving to value diverse perspectives and address the inequalities within the field.

### 1.3. Rehabilitation and Support Services

In the UK, the care of individuals with moderate to severe TBI has largely focused on reducing mortality rates. Development of hospital care, acute neurosurgical and critical care, and early-stage inpatient rehabilitation have contributed substantially to this aim, which has been successful (NICE, 2014). The establishment of the major trauma centre (MTC) network has played an important role in improving survival rates for patients with severe injuries, primarily by facilitating rapid response times and access to specialised interventions (Moran et al., 2018). However, ensuring optimal recovery outcomes continues to pose a substantial challenge.

A key issue is the lack of comprehensive and structured care pathways for TBI. Many individuals who do not require intensive neurosurgical or critical care are often treated by generalist clinicians rather than specialists (Li et al., 2021). These patients may receive care instead from various non-neurological hospital departments and are regularly discharged without adequate follow-up or access to specialist rehabilitation services. This gap in care disproportionately impacts older adults, who are more likely to sustain TBIs from low-impact incidents, such as falls (Coats, 2020).

The challenges in TBI care are compounded by the "hidden" nature of its long-term effects. While physical impairments are more readily observable and diagnosable, the primary causes of disability, cognitive, emotional, and behavioural impairments, are often less apparent (Davis, 2005). Moreover, the "frontal lobe paradox" complicates the diagnostic process, as survivors may perform well on standardised tests or in conversation yet struggle significantly with everyday tasks. These difficulties can severely impact a survivor's journey to return to work and/or resume social roles. Consequently, rehabilitation efforts can become fragmented, with impairments going unrecognised or being identified only after considerable delay. Although changes in healthcare, such as the establishment of the MTC, have enhanced the early stages of rehabilitation, there remains a critical need for specialised, ongoing support and well-defined pathways to address the long-term complications of TBI (Li et al., 2021).

## 1.4. Difficulties following TBI

### 1.4.1. Position statement

Brain injury often leads to significant and life-long physical and psychosocial difficulties for survivors, which will be discussed below. However, many of the studies and literature that will be discussed utilise pathologising, reductionist and clinical language. Indeed, the literature often privileges the voices of the carers or clinicians. Equally, the language used is highly medical, reflecting the main areas of research (namely neurology) which have produced most of the research discussed. This lack of "ownership", can construct a position of disempowerment, and the author seeks to acknowledge a critical realism point, which will be threaded throughout the thesis. It will not always be possible to do so in discussing research, which has a focus on cognitive deficits, psychiatric symptoms (and measures), and corresponding terminology. However, where possible and in line with the British Psychological Society (BPS) guidance, the author will seek to reflect the holistic and individualised ways of understanding phenomenology and distress, central to one pillar of clinical psychology, formulating a person's lived experience.

### 1.4.2. Mental health

TBI is a complex condition often accompanied by a range of mental health challenges that make life after injury more difficult. Mental health issues are distressing for survivors and their families but also carry substantial societal and economic consequences. Among the most common conditions associated with TBI are anxiety and depressive disorders. Reviews have found prevalence rates for anxiety disorders as high as 70% following TBI, and rates of depressive disorders varying from 25% to 50% (Moore et al., 2006; Osborn et al., 2014). These conditions frequently co-occur, further complicating the clinical picture. The presence of such mental health difficulties is strongly linked to poorer functional outcomes, and female gender has been identified as a specific risk factor for developing anxiety and depression following TBI (Oyewsanya & Ward, 2017).

The treatment of anxiety and depression in individuals with TBI is particularly challenging due to the limited research on effective psychological and pharmacological interventions.

Traditional randomised controlled trials (RCTs), the gold standard for researching interventions, are often ill-suited to this population due to the heterogeneity among TBI survivors. Some evidence suggests that modified cognitive-behavioural therapy (CBT) can be effective in treating mood and anxiety disorders for people with TBI. However, these studies are typically small, with varying level of quality in their methodology, limiting their generalizability and making it challenging to consolidate findings into actionable recommendations (Soo & Tate, 2007). Unsurprisingly, many survivors with these issues do not receive adequate care. The complex and multifactorial aetiology of these disorders further complicates treatment. Mental health difficulties following TBI may arise directly from the primary brain injury, develop as secondary effects, or be mediated by the broader impacts of the injury (Strakowski et al., 2013). The possible multifaceted nature of mental health difficulties following TBI contribute to the variability in treatment effectiveness, further reinforcing the need for individualised support.

### 1.4.3. Physical disability and health-related quality of life (HRQoL) after TBI

TBI is frequently accompanied by significant physical disabilities, the extent of which depends on the injury severity, location, effectiveness and timeliness of rehabilitation interventions. Physical impairments commonly include motor dysfunction, such as hemiparesis, or ataxia, alongside sensory deficits, spasticity, and chronic pain (Corgoraptis et al., 2019). Consequently, survivors often face challenges in changed mobility and difficulties with gait or balance, which can necessitate equipment such as walkers or wheelchairs. Impairments may present more subtly, affecting fine motor skills, impacting daily routines or activities, such as dressing or cooking, and affecting the survivor's autonomy. Fatigue is a hallmark of TBI, which also affects activity levels and can be a barrier to rehabilitation engagement and wider social reintegration for survivors.

Nevertheless, with suitable rehabilitation, many survivors regain function in physical mobility, and impairments can be diminished compared to the onset of the injury. Critical to this are MDT approaches, consisting of physiotherapy, occupational therapy, and speech therapy. However, outcomes and interventions are influenced heavily by the timings and intensity of rehabilitation interventions. Despite the recognition of this, a substantial proportion of survivors experience chronic disability and do not receive long-term and/or intense rehabilitation (Mostert et al., 2022). Disparities in access to services further compound these challenges, which, as discussed, intersect with systemic discrimination based on gender or race, which impacts the long-term outcomes following TBI.

In measuring the outcome of the long-term impact of TBI, health-related quality of life (HRQoL) is often utilised as it captures the broad changes that can follow a TBI and impact survivors' well-being, providing a comprehensive measure of how the injury affects survivors' lives. TBI survivors report significantly reduced HRQoL, due to heightened difficulties with physical, cognitive, and emotional impairments (Mostert et al., 2022). The relationship is bidirectional, whereby physical impairments (and others) directly reduce HRQoL by limiting autonomy and mobility, while reduced HRQoL may negatively impact recovery, affecting motivation and adherence to rehabilitation.

### 1.5. Biopsychosocial model of TBI

Formulation is a fundamental competency of clinical psychology. Using formulation, therapists and clients can collaboratively develop shared understandings of clients' lived experiences, normally through the lens of a particular theoretical model. In essence, formulation represents an endeavour to make sense of a presenting situation. However, conceptualising an individual's experiences following a traumatic brain injury (TBI) can be challenging, as these experiences are multifaceted, often under-supported, and frequently under-recognised.

A range of models may be drawn upon when working with individuals who have sustained a TBI, depending on the issues presented. Models of cognition, emotional functioning, behaviour, and learning have all been applied within clinical psychology and TBI, each demonstrating variable levels of utility and success (Snell et al., 2009). More recently, there has been a shift toward more comprehensive models of neuropsychological rehabilitation and post-injury life.

It is important to recognise how a survivor's cognitive impairments intersect with their family system, premorbid personality, lifestyle factors, and goals. Equally, it is important to consider pre-injury beliefs, values, and goals at individual, familial, and cultural levels to facilitate a holistic understanding of a person's lived experiences. An important aspect of developing a neuropsychological formulation involves understanding the nature and consequences of brain damage on a survivor's functioning. This often requires interpreting physical health reports, scans, clinical notes, and, where appropriate, more detailed neuropsychological assessments. This process can support therapists to identify a client's strengths, and deficits and inform targeted rehabilitation. The timing of assessment and intervention is also important, as TBI recovery may continue for an extended period, often longer than that observed in other neurological conditions, such as encephalitis (Wilson, 1998).

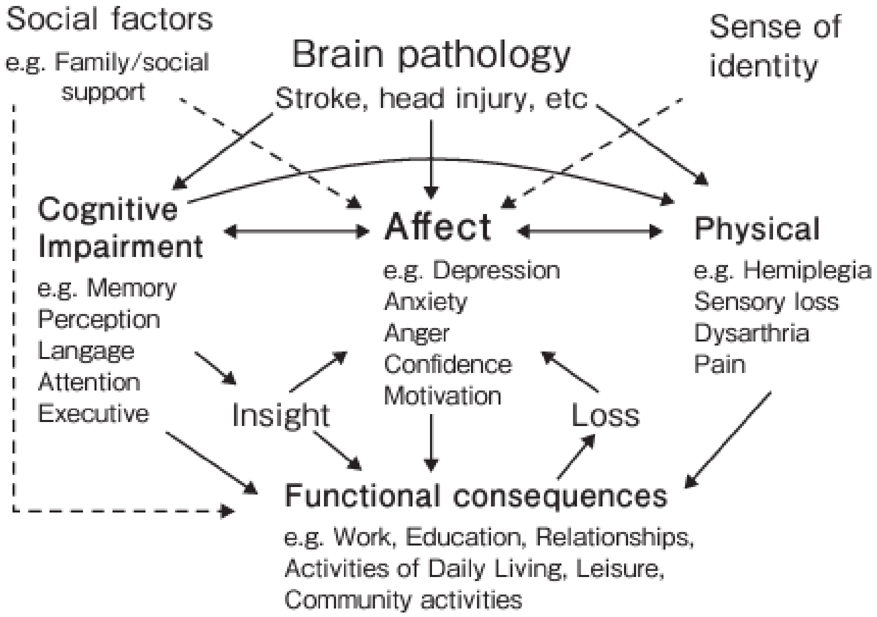
In addition, considering the consequences of the injury often reverberate throughout the individual's broader support system, it may also be helpful to draw on systemic models of therapy. These can inform the involvement of family members and significant others, offering the possibility that support and intervention provided "by proxy" can support recovery.

Nonetheless, implementing formulations consistently within teams and with clients remains a challenge. Still, clinical psychologists, due to their training and positioning in interdisciplinary teams, are well-placed to present and integrate holistic models into broader rehabilitation efforts (Geach et al., 2018).

A biopsychosocial model of brain injury has been utilised in research and clinical practice as especially valuable in guiding holistic formulations (See Figure 1). Such a framework not only helps to conceptualise a patient's needs but also informs the development of meaningful, collaborative rehabilitation goals that are aligned with personal values, life roles, and social supports. In doing so, recommendations can then be made by clinicians and MDT's.

**Figure 1**

*The Oliver Zangwill Centre biopsychosocial formulation framework (Evans, 2019).*



## 1.6. Cognitive changes following TBI

The following section will concentrate on the most common cognitive complaints. The following section will concentrate on the most common cognitive difficulties experienced by TBI survivors. It is important to acknowledge that TBI is a risk factor in developing neurodegenerative conditions, such as dementia (Nordström & Nordström, 2018). However, this section will not explore this long-term risk factor.

### 1.6.1. Memory and TBI

Memory loss is one of the most common and debilitating effects of traumatic brain injury, impacting over 60% of TBI survivors (Ernst et al., 2018). Memory loss and subsequent confusion are often associated with the early stages following a brain injury, generally termed "post-traumatic amnesia". As patients recover, post-traumatic amnesia normally also recovers; however, memory difficulties often persist following recovery. To this end, memory and TBI appear to be intrinsically linked. The hippocampus and cortex, brain regions significantly involved in the memory process, are often damaged following TBI (Graham et al., 1995).

Memory has traditionally been categorised into short-term or long-term. This has been criticised as being vaguely defined. In particular, short-term memory measures do not correlate well with cognitive aptitudes and other measures of cognition and memory (such as working memory) that do correlate well with cognitive aptitudes (Cowan, 2008). Consequently, research has moved towards conceptualising the concept of "memory" within working, episodic, and semantic memory. Episodic memory refers to the ability to consciously recall personal episodes or experiences; it is unique among the other conceptualisations of memory due to how it is intrinsically related to a sense of self and a sense of time (Matthews, 2015). Working memory is defined as the cognitive ability to transiently hold, process, and manipulate information (Diamond, 2013). Semantic memory differs as the retrieval of memorised facts or events, and their meanings that a person may or may not have had personal experience with (e.g. recounting the periodic table) (Pause et al., 2013). It should be noted that memory is a complex cognitive process, and does not exist in isolation. Memory relies on and is mediated by attention, processing speed, and higher-order executive functions, which are also domains frequently disrupted following TBI. Anterograde long-term episodic memory, which is the ability to create new memories of upcoming and current events, is amongst the most well-documented and studied deficits following TBI (Polin et al., 2023). However, the physiological mechanisms underlying episodic memory deficits are still not fully understood.

Research suggests memory rehabilitation can be useful for people with memory deficits following TBI, and strategies should be employed to re-establish access to information or compensate for those deficits. There is evidence for the usefulness of spaced retrieval practices, which capitalise on spacing and testing effects to aid new learning (Cicerone et al., 2011). Although there is some inconsistency in its efficacy, large effect sizes of its ability have been shown (p,.001, n2= .72) (Sumowski et al., 2014). A comprehensive approach to memory rehabilitation can involve assessing the memory profile across multiple subtypes, verbal versus visual memory, working memory capacity, and storage versus retrieval difficulties, to guide interventions. For instance, visual supports and spatial mapping strategies may benefit those with relatively intact visual memory systems, while encoding techniques such as rehearsal, chunking, and linking new information to pre-existing knowledge can enhance retrieval (Cappa et al., 2005). Identifying strengths and difficulties in a survivor's memory also allows survivors to adjust expectations and circumvent difficulties by relying on strengths. Ultimately, optimal rehabilitation efforts should be personalised, taking into account each patient's unique cognitive profile (Ernst et al., 2019). For many survivors, however, memory function does not return to baseline or near-baseline levels. For these people, external memory aids such as calendars, timers, and notebooks can be employed as "cognitive prosthetics," providing cues that support the encoding and retrieval of information. These compensatory strategies can be used in conjunction with organisational skills training to circumvent memory deficits and maintain greater independence (Velikonja et al., 2014).

### 1.6.2. Executive Functioning and TBI

Executive functions (EF) represent higher-level cognitive abilities that underpin many aspects of social cognition and interpersonal behaviour, such as attention control, inhibition, theory of mind, planning, and problem-solving (Anderson et al., 2002). Due to its location, these processes are largely attributed to the pre-frontal cortex and are especially vulnerable to mechanical forces associated with TBI (Bigler, 2013). This presents a significant potential challenge to TBI survivors and those around them, as intact EF is critical to the ability to engage in daily life and adapt to an ever-changing world. It is unsurprising that EF dysfunction is associated with impairment in function and survivors' ability to engage in daily life activities (Chan-Weiner et al., 2002).

For many TBI survivors, EF may not return to baseline. For these people, compensatory approaches can be useful. For example, Goal Management Training (GMT) and auditory cueing techniques (such as sending "STOP" text messages to support attention) have shown promise (Cicerone et al., 2011). However, implementing these strategies requires nuance. Survivors with more pronounced EF deficits may lack insight into their post-injury changes, indicating that environmental modifications and caregiver support are often needed to provide ongoing structural support and cueing (Tate et al., 2014). Moreover, comorbid memory difficulties are often present, which may interfere with learning compensatory strategies. This further highlights the importance of goal-related rehabilitation in supporting survivors with manageable and "smart" goals, which can help stoke motivation to engage in neurorehabilitation interventions.

Specific subskills of EF, such as cognitive flexibility, working memory, and emotional regulation, are particularly important in social functioning, which can be impacted following TBI (Milders et al., 2008). Executive dysfunction can severely affect aspects of social cognition, for example, by impairing emotion recognition, impacting empathy, and social cue interpretation. These difficulties can lead to interpersonal difficulties and changed personalities or behaviours, impacting relationships and survivors' integration back into everyday life. These difficulties can be significant and affect their wider social network, increasing caregiver burden and risk isolation for both survivors and their families.

## 1.7. Assistive Technology in Brain Injury Rehabilitation

Technology has transformed the way we live. We have designed and developed technology to extend our own functioning throughout history, from the bow to extend our ability to throw or a car to extend our ability to travel. Technology has revolutionised the way in which we live and will continue to do so. It is an integral part of most people's daily functioning.

Assistive technology for Cognition (ATC) refers to technologies that "can be used to enable, enhance, or extend cognition function" (O'Neil and Gillsepie 2014, p.1). Whilst this definition encapsulates the various applications of ATC, ATC is ultimately what the person chooses to use. Bouck (2010) described ATCs as technologies that can be broken down into low, moderate, and high. Low technology includes all non-digital artefacts that may help thinking and remembering, such as written lists. Moderate technology refers to non-computerised electronic devices such as a calculator. High technology includes computerised devices such as smartphones and tablets (Desideri et al., 2020). Every tier of ATC can be used to compensate for cognitive impairments, but high technology is considered more effective than low technology-based strategies due to the broader range of features they encompass, e.g. a smartphone can send prompts, contain electronic calendars and can be used to record notes. ATC's can range from basic everyday things such as calendars or a wristwatch to highly specialised devices such as PDAs or software applications. There has been a universal and rapid development in technology over the last 10 years and as such, ATC's (and indeed technology) is available at essentially affordable costs. Moreover, TBI survivors increasingly have existing technology that can be used in compensatory ways.

This is a significant change from the previous state of ATC for cognition. A boom in research in the area occurred in the 90's, highlighting the potential benefits of ATC for various disabilities, including TBI, but also for people with learning disabilities and neurodegenerative conditions. Often, specific technologies were created for interventions in the literature, customised to the specific needs of invidious clients. Items such as PDAs, tailor-made electronic watches, and software programming that altered and scheduled appointments were trailed (Cole et al., 2000). There was evidence of the efficacy and usability of these interventions. However, a persistent barrier was the high cost of developing and customising these technologies for individual users, which often compromised their broader usability across different populations. These technologies were more often trailed and utilised in clinical contexts rather than the community, which is primarily where those with TBI live, resulting in the ecological validity of such interventions being unclear (Frank et al., 2004). Indeed, checking a brand new PDA device for the next therapy appointment is fundamentally different to using it to remember to go to the supermarket.

### 1.7.1. AT for Memory Support

Assistive technologies for memory support typically fall into two primary categories: prospective memory aids and retrospective memory aids. Prospective memory aids are designed to help users remember future tasks or events, often by using prompts. Common devices include smartphone apps, electronic calendars, pagers, and PDA's that provide multi-modal reminders through auditory, visual, or tactile cues (Charters et al., 2015). Integration with alarms or notifications, electronic calendars are widely used, allowing users to set reminders for specific times and tasks. "Prompting" has shown promise in reducing the frequency of missed appointments and enhancing adherence to routines (Jamieson et al., 2014)

Retrospective memory aids, which are less commonly referred to in the literature, support recall of past events or information. Some advanced systems offer features like audio or visual playback to assist users in reviewing recent activities and reinforcing memory for events or tasks completed earlier (Linden et al., 2016). In clinical settings, both prospective and retrospective memory aids are used to support individuals in activities of daily living (ADLs), with the choice of device tailored to the user's cognitive profile and individual needs based on daily routines.

The way assistive technologies deliver memory support varies significantly across devices and studies. For prospective memory aids, reminders are typically event or time-based, aiming to prompt the user at the most appropriate moment for task completion. For instance, smartphone applications may send notifications to remind users of an upcoming appointment, while wearable devices may vibrate to prompt task initiation. The use of event-based cues, such as location-based alerts (e.g., reminders to enter a shop when nearby), is particularly effective for prospective memory, helping users initiate tasks with minimal delay (de Joode et al., 2012)

Studies on these technologies often report varying levels of user satisfaction and adherence, which is likely influenced by the ease of use and customisation available. For example, devices requiring frequent manual input may see lower engagement, particularly among individuals with severe cognitive impairments. More straightforward applications, such as digital calendars with pre-set notifications, are generally associated with higher adherence but may lack the nuanced support needed for more complex memory tasks (Gillespie et al., 2012).

Research evaluating the efficacy of memory assistive technologies has resulted in mixed results. While some studies report positive outcomes, such as improved task adherence and reduced dependence on caregivers, others highlight significant variability in the success of these interventions. For example, Charters et al. (2015) found electronic reminder systems effective in supporting routine management for individuals with ABI, suggesting a moderate impact on day-to-day functioning. However, the extent of benefit varied based on the user's familiarity with technology, the severity of memory impairment, and the fit between the device's features and the individual's specific memory difficulties. Additionally, there is a wide diversity of methodologies used in studies on TBI which makes direct comparison of outcomes challenging. Many studies employ different outcome measures, ranging from self-report questionnaires on user satisfaction to objective measures of task completion. Furthermore, the varying quality of the research, with limited randomised controlled trials and a reliance on single-case experimental designs, has made it difficult to establish definitive efficacy standards for memory assistive technology (Jamieson et al., 2014).

### 1.7.2. AT for executive functioning

In their seminal review of assistive technology for cognition, Gillespie et al. (2012) used the World Health Organisation International Classification of Functioning (ICF) framework to review applications of technology in relation to specific domains of cognitive functioning. The ICF does not specify "Executive Functioning" but does describe "higher level cognitive functions", which are divided into cognitive functions that enable abstraction, organisation and planning, time management, cognitive flexibility, insight, judgement, and problem-solving. In their review, they observed that most ATC's to support EF aimed to assist with time management, organisation, and planning. For example, among the technologies they identified are systems such as COACH, which employs artificial intelligence (AI) to guide adults with dementia through ADLs using audio and video prompts (Mihailidis et al., 2008).

A recent comprehensive review of AT for EF found that most tools assist with procedural or navigational tasks through prompting and cueing but rarely focus on helping users formulate goals prior to action (Spalla et al., 2024). Of the populations studied, only 24% comprised individuals with TBI, highlighting a general lack of research into this area for survivors of TBI. In the research on TBI, this support frequently takes the form of mobile applications or wearable devices that provide structured reminders and help sequence tasks. Tools such as PEAT (Planning and Execution Assistant and Trainer) are specifically designed to support individuals with brain injuries, offering real-time adjustments to task prompts based on user performance. By delivering cues at scheduled intervals or as triggered by contextual factors, these technologies can significantly support difficulties with time management, task switching, and maintaining overall goal-directed behaviour (Desideri, 2020).

However, the effectiveness of EF-supporting AT in TBI populations’ remains mixed, with pronounced individual differences in responsiveness. Spalla et al. (2024) report that while reminder systems can improve routine adherence for some, outcomes vary significantly depending on the cognitive demands of specific tasks, the complexity of the technology, and the user's level of engagement. The variability in results is further exacerbated by a lack of standardisation in both AT design and research methodology. Studies employ a wide range of outcome measures, from task completion rates to user satisfaction, making it challenging to reach definitive conclusions about the efficacy of these technologies.

One fundamental challenge in evaluating EF focused AT is the complexity of the executive processes themselves. Time management and planning, which are both EF subskills, are distinct cognitive skills and, therefore, while they both sit under the umbrella term of EF, may require separate or overlapping interventions. Evidence suggests that simpler prompting devices are often more effective for those with moderate deficits. At the same time, individuals with more severe EF impairments may need context-aware technologies capable of adapting to real-time challenges and changing user states (Desideri et al., 2020).

### 1.7.3. Complexity and Limitations in current ATC's

Current ATCs designed to support individuals with TBI face numerous challenges. Chief among these are issues related to complexity and cognitive load. Users who experience reduced cognitive flexibility, working memory, and attention often find it challenging to learn, navigate, and maintain engagement with these tools. Similarly, those with memory impairments may struggle to learn how to use these technologies and remember to use them regularly. As a result, there is a paradox: tools intended to assist can instead overwhelm the user or remain unused, ultimately limiting their efficacy and sustained use.

User-centred design practices that produce intuitive and accessible technologies tailored to individuals with TBI are not yet standard. Spalla et al. (2024) concluded there is a need for ATC's to employ iterative, user-centred approaches that account for common cognitive constraints. Given the recency of their review, it is apparent that the field of ATC still has significant room for growth. Additionally, the extent to which ATC's are being used in clinical practice is unclear. Few ATCs have undergone rigorous, TBI population-specific testing to establish their suitability and efficacy, and even fewer studies address the important issue of long-term adherence. Without these bodies of research, developing standardised guidelines or best-practice frameworks remains challenging, leaving clinicians and services in a grey area regarding the implementation of ATC interventions. This gap highlights a pressing need for more research.

## 1.8. Clinical Psychology within Neurorehabilitation

Clinical Psychology is a discipline that bridges scientific inquiry with clinical practice. It aims to improve well-being and alleviate distress. Clinical psychologists are often part of leadership teams within healthcare. Training for clinical psychologists includes engaging in research and therapeutic skills, equipping them to work as "scientist-practitioners ".

In the field of neurorehabilitation, clinical psychologists work to provide a person-centred, clinical, philosophical approach to care across the lifespan for people with neurological conditions (Stucky et al., 2024). The practice incorporates assessment, intervention, and MDT work. Within clinical psychology, it is possible to specialise in clinical neuropsychology. However, the journey to becoming a registered clinical neuropsychologist is long in the UK, limiting the number of clinical neuropsychologists present in services. As such, this thesis will discuss clinical psychology more broadly, as many clinicians who are not registered as clinical neuropsychologists will be working within neurological services and with TBI.

Clinical psychologists are likely to be familiar with various models but are primarily trained in CBT in the UK. They often draw upon and integrate numerous models and theories to meet the needs of services and client groups. Frameworks within neurorehabilitation have proposed the use of systems theory and positive psychology to integrate strength-based approaches into research and clinical practice.

A critical issue in neurorehabilitation research is the limited generalizability of even well-designed randomised controlled trials (RCTs) to real-world clinical practice. The stringent selection criteria and highly standardised interventions often result in findings that fail to translate effectively to the complexities of clinical settings (Stucky et al., 2024). Disorders resulting from traumatic brain injury (TBI) exemplify this challenge, as they are multifaceted and encompass interrelated issues in bodily function, physiological processes, and psychosocial well-being. As "scientist-practitioners," clinical psychologists are uniquely positioned to address these challenges. Their training, practice, and leadership role within teams position them well to design and conduct clinically relevant research, which can then inform clinical practice. Combined with the profession's commitment to professional and social change, which matches the values of the NHS, there are lots of reasons why clinical psychologists should "do research," and this can be applied well to the barriers and difficulties in research ATCs.

## 1.9. Research aims

The aim of this research is to contribute to the current and fast-moving body of research on ATC, with an emphasis on how it can be applied to TBI populations. The general field of enquiry will be the experience of utilising the current technology available in clinical practice from the perspectives of clinicians working in neurorehabilitation. Through exploring these experiences, this research aims to understand what enables ATC intervention, what barriers exist, and what can be learnt to inform future research and clinical practice.

## 1.10. Reflexive statement

I am a trainee clinical psychologist, completing my professional doctorate in clinical psychology, and this thesis forms a substantial and final part of my training. I am interested in technology, and since entering healthcare, I have explored its potential uses within these settings. I previously worked with individuals affected by neurodegenerative conditions, where I experimented with virtual reality interventions. During this experience, I became aware of a notable lack of guidance and research in this rapidly evolving area, despite the enthusiasm and curiosity expressed by clients and other clinicians.

Later, while working in stroke and neurorehabiliation services, I again observed similar patterns, except this was during the COVID-19 pandemic. During this time technology permitted new ways of working, often out of necessity, which was exciting and useful. However, I also became acutely aware that certain group, including older adults and those from more deprived backgrounds, risked being left behind due to inequitable access to technology.

My interest in this topic also intersects with my current clinical role. I currently work within an older adult team in the NHS, including in a memory service. I frequently encounter a lack of structured support for individuals following a cognitive impairment diagnosis, which mirrors my earlier experiences when I began my career.

For these reasons, I have a personal and professional interest and investment in this area of research. I believe that technology holds enormous potential to enhance healthcare and people's lives, yet falls short of what it could achieve. As a clinician I am committed to equitable healthcare and access to services, and am therefore motivated to explore this area of research, into how we can harness technology more effectively and inclusively for such a disadvantaged group of people as TBI survivors.

# 2. Chapter Two- Narrative Literature Review

The introduction chapter provided an overview and context to the present research. This chapter builds on this by engaging in a narrative literature review of the relevant literature. The aim of the review is twofold. Firstly, it seeks to synthesise the existing literature in a narrative synthesis regarding the efficacy of smartphone-based assistive technology for Cognition (ATC) in supporting memory and executive functioning. Secondly, the review aims to understand the mediating role of ongoing support and training in regard to ATC's efficacy.

## 2.1. Current literature

Traumatic brain injuries (TBI) affect an estimated 69 million people globally each year (Dewan et al., 2018). As outlined in the previous chapter, individuals living with TBI often experience cognitive impairments that profoundly impact their everyday lives. These impairments frequently manifest as difficulties with episodic memory, whereby past events are poorly recalled, or as amnesic presentations. More commonly, however, TBI affects prospective memory, compromising survivors' ability to remember and execute future tasks such as attending appointments or taking medication. The resulting loss of independence can be tremendous, often necessitating reliance on formal or informal caregivers for support.

Rapid technological advances have introduced new opportunities for integrating technological solutions into healthcare and neurorehabilitation. One emerging area of promise is the compensatory application of technology, particularly assistive technology for cognition (ATC). Unlike interventions focused on retraining cognitive skills, ATCs are external aids, offering compensatory rather than directly supporting the improvement of a cognitive skill. As O'Neill and Gillespie (2014) define it, ATC refers to technologies that "enable, enhance, or extend cognitive function" (p. 1).

Among the myriad of devices available for ATC, smartphones hold particular promise due to their versatility and ubiquity. Smartphones consolidate a range of functions previously found across multiple devices and are highly customisable through their operating systems and apps. This adaptability positions smartphones as an ideal platform for ATC, particularly in neurorehabilitation contexts. Moreover, they are pervasive in everyday life; 84% of adults own a smartphone (Statistica, 2024). This widespread use provides clinicians with a unique opportunity to build on users' existing familiarity and skills rather than introducing entirely new technologies and routines. Smartphones are equipped with multiple features that make them ideal for ATC, including internet connectivity, mobile communication, sensors, geolocation, notifications, and the ability to install a wide array of customisable apps (Putzer & Park, 2012).

Nevertheless, whilst the figure of 84% of smartphone ownership may seem unsurprising, given their ubiquity in modern life, it warrants a critical appraisal in the context of TBI population and those from lower socio economic backgrounds (LSES). Such statistics are likely inflated by higher rates of ownership among working-age, neurotypical, and economically advantaged groups, and may not accurately reflect access within marginalised populations. Moreover, ownership alone does not equate to meaningful access; exclusion may be compounded by cognitive impairment, low digital comfort, or lack of support. Nevertheless, access to smartphones is higher than in previous decades, and outright device ownership may be less of a barrier than the affordability of internet access, mobile data, and transport to and from neurorehabiliation clinics.

Furthermore, there is currently no effective pharmacological treatment for the cognitive deficits associated with TBI, and survivors face an increased risk of developing neurodegenerative conditions that can exacerbate these difficulties (Karakaya et al., 2013). Cognitive enhancements and neurostimulants do exist that have been assessed in their usefulness to support cognitive deficits following TBI. Nevertheless, the long term benefits of most medication are not supported by current evidence, and the latest guidelines from the Internal Cognitive Guidelines (INCOG) continue to emphasis non-pharmalogical interventions rather than pharmaceutical (Jeffay et al., 2023)

There is growing evidence of ATC's efficacy. In 2012, Gillespie et al. conducted a seminal systematic review of the research base on ATC's, which has since become a cornerstone in the field. Synthesising evidence from 91 studies, they identified that technology had been utilised to support various cognitive domains, including memory, attention, calculation, emotion, navigation, and higher-order cognitive functions such as planning and impulse control. They concluded that there was evidence supporting ATC's ability to support cognition across these domains, particularly memory and EF. Notably, most studies (63%) focused on reminding and prompting interventions, suggesting that these functions hold significant potential. Furthermore, Gillespie et al. anticipated that smartphones would become the predominant platform for ATC research and interventions due to their increasing availability and technological capabilities. However, they also highlighted significant limitations in the literature, noting that most studies were descriptive, prioritising ATCs' design and description over rigorous evaluation of their efficacy. Gillespie and colleagues highlighted a gap between the potential of ATCs and their integration into clinical practice.

Since their review, a number of reviews have built upon their findings. Jamieson et al. (2014) reviewed 32 single-case experimental designs (SCEDs) and 11 group studies, seven of which were included in a meta-analysis. The meta-analysis revealed a large effect size (d = 1.27, n =

147) supporting the efficacy of ATCs for individuals with memory impairments. However, the effect size for interventions in SCEDs was medium overall, with stronger effects evident for micro-prompting devices than prospective prompting devices. Their review included study samples involving any brain injury or neurological/degenerative disease, resulting in heterogeneity of injury aetiology (e.g., stroke, trauma, encephalitis, multiple sclerosis, dementia). As a result, they could not ascertain the efficacy of ATC's specifically for memory functioning in TBI populations. Charters et al., (2014) conducted a review of electronic portable assistive devices for individuals with ABI. They identified insufficient evidence to recommend these devices as a practice standard due to the lack of well-designed randomised controlled trials (RCTs). However, sufficient evidence was found to support the use of electronic reminder systems (e.g., personal digital assistants, smartphones, voice recorders) as a practice guideline to support everyday memory.

Kettlewell et al., (2018) evaluated the efficacy of "personal smart technologies" for improving independence, goal attention, fatigue, or quality of life after ABI. While their review did not focus specifically on memory, they included ATC's commonly used for prospective remembering (e.g., personal digital assistants, smartphone applications, mobile messaging). Analysing six high-quality RCTs, they conducted a meta-analysis on four studies. Despite acknowledging the RCT's methodological rigor, they found no significant effects on the outcomes studied. They concluded that there was insufficient evidence to support their clinical use. However, they hypothesised that the lack of tailored device selection to individual needs may have contributed to these findings. Ownsworth et al. (2023) reviewed 19 studies, including four RCTs, five SCEDs, and ten pre-post or single-case studies without experimental control. They found empirical support for the efficacy of ATCs in TBI applications, particularly in supporting different phases of memory. However, they highlighted gaps in understanding what mediates successful ATC applications and the design features that enhance or hinder their usefulness. They emphasised the importance of involving TBI survivors in the development of future technologies to address these gaps effectively.

Assessment of ATCs for EF follows a similar pattern, with fewer literature reviews focusing on EF in TBI populations. Desideri et al. (2020) conducted a scoping review of ATCs for EF in individuals with autism. Analysing 15 studies, they categorised ATCs into context-aware and mobile technologies and used the cognitive process taxonomy proposed by the International Classification of Functioning (organisation and planning, time management, cognitive flexibility, and insight). Their findings revealed limited evidence of efficacy, with only interventions targeting insight demonstrating potential efficacy. However, these results primarily pertained to younger populations (ages 11–17) with autism, which cannot be generalised to TBI populations. Jamieson and Evans (2014) conducted a review of ATCs and EF, echoing previous findings by identifying a lack of robust clinical trials and methodological rigour. Their review lacked transparency regarding methodology, making it challenging to evaluate their conclusions. Nevertheless, they emphasised the need for researchers and clinicians to consider issues of design, accessibility, availability, and adaptability in ATC development and use, echoing similar reviews. A more recent review by Spalla et al. (2024) focused on ATC's for EF in TBI and dementia populations. They identified that ATCs often targeted procedural or navigational tasks, with planning being the most supported EF function. However, they noted a lack of interventions supporting goal formulation, a critical EF function often impaired in TBI. Spalla et al. also highlighted the importance of design, at risk of overburdening users cognitive load. They also emphasised the need for more observational studies and specificity in addressing the severity of cognitive impairments.

## 2.2. Study Aims

The present review seeks to build off the Gillespie and colleagues review. A narrative synthesis has been selected as the most appropriate methodology to collect and make sense of present evidence due to the heterogeneity of study designs, participant characteristics, and outcome measures within assistive technology for cognition literature. Utilising this framework the efficacy of smartphone-based assistive technologies to support memory and EF in individuals with TBI will be evaluated, which has not yet been done. The review will integrate findings across various methodologies but will focus on TBI populations to understanding of ATCs' current use in this group of people. By examining the role of support and implementation, this synthesis also aims to offer an understanding of how training and external support mediate successful and sustained use of smartphone-based ATCs.

## 2.3. Methods

### 2.3.1. Narrative Synthesis

The protocol for this review was guided by Ferrari’s (2015) guidance for best practice when writing narrative style literature reviews. Ferrari outlines a structured and methodological rigorous approach to conducting narrative literature reviews, despite their inherently non-systematic nature. Ferrari emphasises that high-quality narrative reviews benefit from clear inclusion and exclusion criteria, comprehensive but transparent search strategies, and a critical assessment of the literature. While lacking formal guidelines akin to the Preferred Reporting Items for Systematic review and Meta-Analyses (PRISMA) for systematic reviews, Ferrari advocates that by adopting these structures bias is reduced and clarity and quality are improved. Ferrari recommends structuring the review around conceptual frameworks or thematically grouped findings, with clear sections to support synthesis and interpretation.

A narrative synthesis was selected to support the synthesis of results, whilst following Ferrari’s guidance, which is based on textual synthesis. Given the documented limitations of methodological rigour within this area of research, and the heterogeneous nature of TBI populations, statistical synthesis methods, including meta-analysis, was not practical or feasible. This review follows the guidance on narrative synthesis by Popay (2006), who describes four stages: Theory development, developing a preliminary synthesis, exploring relationships within and between studies, and assessing the robustness of the synthesis.

### *Element 1: Theory Development*

Theory development is the established foundation from which the review questions can be formulated and the criteria for which studies are included established. It also supports the rationale behind the review and, to that end, the application of the research and said findings. The literature has established there is a role for ATC's in supporting TBI survivors with cognitive impairments. Despite the increasing evidence of ATC's efficacy, significant gaps exist in the understanding how these tools can be effectively utilised to address specific cognitive impairments in TBI survivors, particularly those related to memory and EF, which are the most common. In light of previous reviews, including the foundational work by Gillespie and colleagues, the present review positions smartphone-based ATC's as the point of query, given their anticipated centrality in the current application of ATC's, and of future of research.

A number of considerations can be drawn from previous reviews that are unclear, but are important: 1) the capacity of smartphone based ATCs to enhance memory and EF in individuals with TBI; 2) the mediating influence of training protocols, refreshers sessions, and support structures (e.g. clinicians, researchers, and family members); and 3) the systemic and ecological factors affecting ATC adoption. As such this review aims to evaluate the efficacy of smartphone based ATC's to support memory and EF in individuals with TBI. It will also examine where training and external support mediate the successful adoption and sustained use of smartphone based ATC's.

### *Element 2: Developing a Preliminary Synthesis.*

This step develops a description of the included studies, organised and described based on terms of effects and/or impact (Popay). This can be done by tabulation, textual descriptions, or groupings and clusters. It is imperative to complete this part of the synthesis to inform the following steps.

### *Element 3: Exploring Relationships Within and Between Studies*

In this stage, patterns that have emerged from the preliminary synthesis are analysed in more detail, and relationships within and across included studies are explored. This element seeks to identify the mediating factors that have influenced the results while trying to understand how and why those interventions worked or did not work (Popay).

### *Element 4: Assessing the Robustness of the Synthesis*

In the final element of narrative synthesis the trustworthiness of the results is assessed. The quality and quantity of the evidence in the synthesis are taken into consideration, and methods used to evaluate these factors are used. The strength of the findings are therefore appraised and judged on their generalisability across different populations and contexts (Popay).

### 2.3.2. Search strategy

Electronic searches on MEDLINE, EMBASE, PsychINFO, PsychArticles, Web of Science were conducted. Following guidance from the PICO framework, three sets of search terms were used in each database, of which related to the population (e.g. TBI, brain injury, ABI), intervention (e.g. assistive technology, AT, memory aid, smartphone), and outcome (e.g. executive functioning, memory, EF; see Supplementary Table A) (Schardt et al., 2007). The PICO framework also outlines the usefulness of a comparison set of terms. However, this was not suitable for this search as designs such as pre-post group studies and some SCED studies that do not use a control were relevant to the search.

Searches were restricted to articles written in or translated into English, published in peer-reviewed journals, and with the full text available. Databases were searched from 2012 to December 2023 in order to build upon Gillespie et al.’s (2012) seminal review of assistive technology for cognition. Their review comprehensively synthesised literature up to 2012, and the present review was designed to extend this work by focusing on more recent developments in the field. Additionally, backward and forward citation searches were conducted on articles that met eligibility criteria.

### 2.3.3. Study selection

Screening of articles was conducted via the web-based software ebshost. Articles were initially screened based on title and abstract of all peer-reviewed full-text articles guided by the following criteria:

a) Sample comprised of adults (minimum age of 18 years) with TBI
b) The study evaluated the efficacy of the smartphone led intervention used by participants, to support memory-related functioning (this included retrospective and/or prospective memory) and/or executive functioning. Participants were therefore expected to be independent in using the smartphone for a clear phase when completing tasks.
c) Outcomes related to either participants self-rated functioning or performance related to the cognitive functioning being supported e.g. targeted memory behaviours, task completion, recall, attainment, rate of forgetting, frequency of memory reminders set, usage of smartphone, number of reminders/prompts required etc) based on pre vs post intervention comparison or post-intervention changes relative to a control/alternative condition or phase.
d) The study design needed to be; randomised controlled trial (RCT), quasi-randomised controlled trial, comparative non-randomized intervention with concurrent controls, single arm (e.g. within-subjects, pre-post design) with a minimum of 10 participants, or single-case methodology with sufficient baseline phase (3 or more data points) prior to the treatment phase. Group studies (>10 participants) were required to report the statistical significance of changes in memory-related outcomes base on a within-group of between group analysis.

Studies were excluded if

a) Individuals with TBI were not responsible for using the smartphone for tasks themselves (e.g. the phone was used solely by a clinician, caregiver, or relative), or if the smartphone was used by a clinician to deliver therapy
b) If participants had brain injuries that would not fall under the umbrella term TBI (e.g. dementia, Alzheimer's, Huntington's disease etc).

c) If the study focused on evaluating different approaches to training rather than efficacy of smartphone as compensation in supporting memory and/or executive functioning.
d) If they did not use a smartphone as the modality of the intervention, therefore excluding other "smart" technologies such as smart watches, tablets, computers, and micro-prompting devices
e) If case studies did not have sufficient data (e.g. <3 baselines data points), group studies not reporting the statistical significance of pre-post changes or between group differences, and studies reporting on outcomes not relevant to the areas of cognition being evaluated.

#### 2.3.4. Quality assessment

Studies were initially grouped according to the Class levels used in reviews of evidence-based cognitive rehabilitation (Cicerone et al., 2000). Class I studies were well-designed, prospective, randomised controlled trials. Within this category, Class Ia studies consisted of prospective designs with "quasi-randomised" assignment to treatment conditions (e.g., allocation to alternating conditions or cross-over designs). Class II studies included prospective, non-randomised cohort studies; retrospective, non-randomised case-control studies; or clinical series with well-designed controls such as multiple-baseline or alternating treatments SCED, as defined by Tate (2020). 32 Class III studies referred to clinical series without concurrent controls (single-arm, pre-post studies), or single-case methodology without multiple baselines or experimental control (i.e., AB designs).

#### 2.3.5. Risk of bias

Selected studies were then further appraised. Class I studies were assessed using the PEDro-P and PEDro+ scale. The PEDro scale has 11-items which assess: eligibility criteria (not included in score), random allocation, allocation concealment, similarity of intervention groups, blinding of subjects, therapists & assessors, retention of >85% of participants, intention-to-treat analysis, between group statistical comparisons, and point and variability measures (Vaezipour et al., 2019).

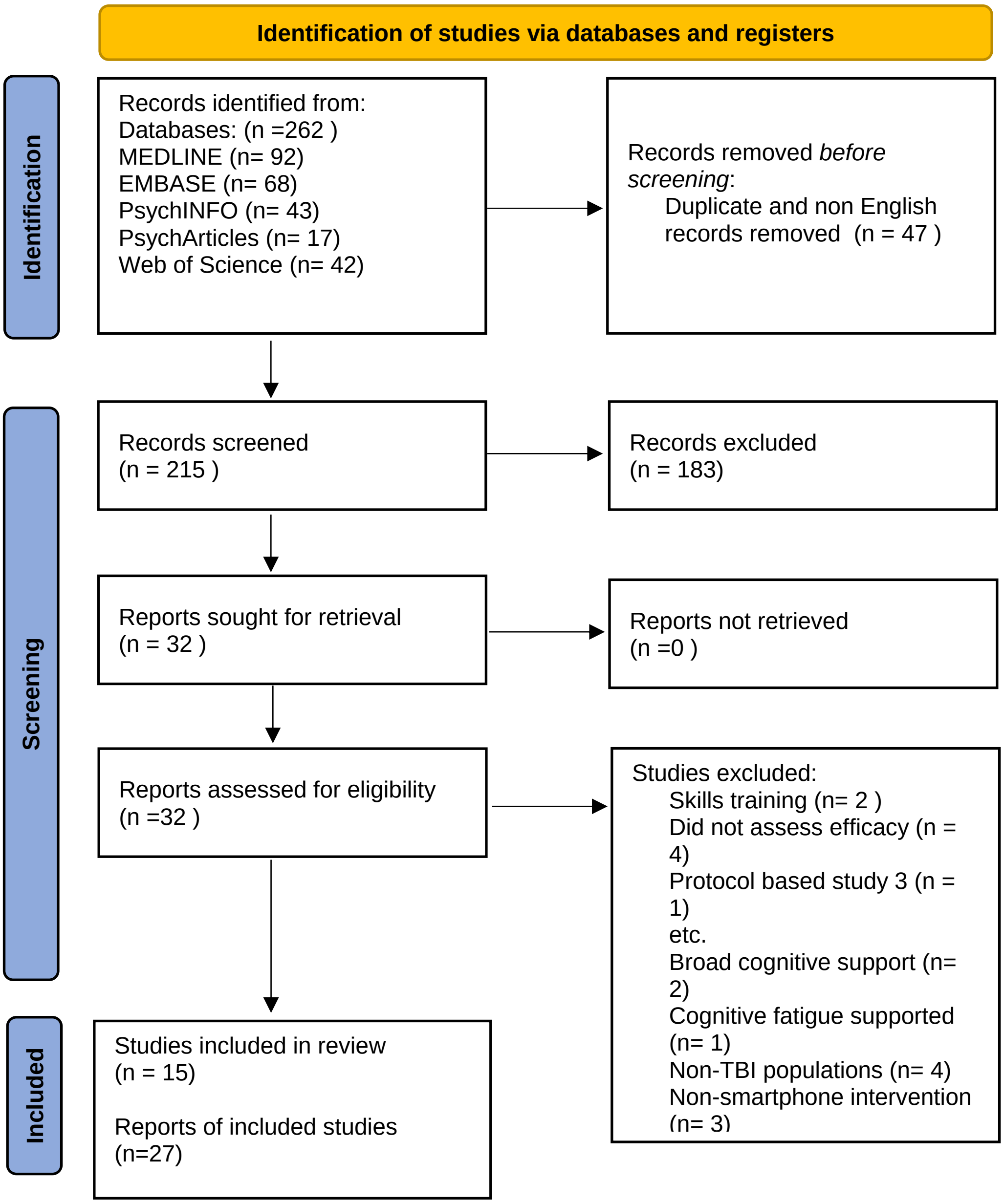
The PEDro- and PEDro+ are scales that assist in assessing whether a clinical trial presents reliable and meaningful results for use in clinical practice (Kamper et al., 2015). It was originally designed for critiquing the research quality of physical therapy clinical trials but has been adapted for other applications and is a reliable method of evaluating the methodological quality of trials (Maher et al., 2003). The original PEDro scale did not address treatment fidelity or treatment replicability, and following Avramovic et al (2023) review of digital health, two additional items developed by Cherney et al (2013) were added. These additional items assess treatment replicability and treatment fidelity, both of which are important elements within clinical research, creating the PEDro-scale. The authors state that scores of 6-8 constitute "good" methodological quality and scores of 9-10 constitute "excellent" quality. They later added PEDro+ items relating to treatment replicability and sufficient detail of the treatment procedure and methodology to enable clinicians or researchers to replicate the treatment accurately, and treatment fidelity, reporting of methods used to examine adherence to the treatment protocol (Cherney et al., 2013).

Class II and III single-case studies were appraised using the 15 items of risk of bias in N-of 1-Trials (RoBiN-T) Scale. The RoBiNT scale is a revision and replacement of the SCED scale which has been designed to provide a comprehensive evaluation of risk of bias, whilst also incorporating features used in the medical N-of-1 trial to strengthen internal validity (e.g. randomisation and blinding), in a compatible way with current designs and standards of SCD's (Perdices et al., 2023). The RoBiNT scale contains two subscales. The first is Internal Validity, which consists of seven items: design with control, randomisation, sampling of behaviour, blinding of patient/therapist, blinding of assessors, inter-rater reliability and treatment adherence. The second subscale is External Validity, which consists of eight items: baseline characteristics, setting, dependent variable, independent variable, raw data record, data analysis, replication and generalisation. As per guidelines by Tate et al (2020) a 3-point scale (0, 1, 2) was used to rate each item

## 2.4. Results

**Figure 2.**

*Flowchart of sources screened and included in the review.*



The electronic searches identified 262 potentially relevant titles, which were reduced to 215 once duplicates and non-English records were removed. A further 183 articles were excluded by title and abstract, leaving 32 articles to be screened as full texts. Once full texts were read through for further evaluation, 15 studies met the full inclusion criteria and were included in this review, as described in Figure 2. A summary Table of the study samples, designs, interventions, primary outcomes and key interventions is presented in Table 1.

It is to be noted a small number of studies included used participants with mixed acquired brain injury (ABI), including but not limited to traumatic brain injury (TBI). In these cases, inclusion was based on the predominance of TBI in the sample or the relevance of the findings to the TBI population, particularly where mechanisms of cognitive impairment and intervention needs were comparable. This decision reflects the challenges of pragmatism in the literature, where diagnostic boundaries are not always clearly reported

Table 1

*Summary of included studies.*

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| Andreassen et al., 2020 | N= 8; 6 male (75%), 2 female; TBI (100%); TSI = not specified | Multi-centre parallel group pilot randomized controlled trial | Use of RemindMe an interactive digital calendar app with reminders | Pps asked to utilise app to set daily reminders for two months; once a week patients had a 15minute conversation with OT’s | Memory | Pps were satisfied with RemindMe app, although this varied greatly | Training given in first session (time unclear) and regular support given during weekly 15 minute sessions over two months | Sweden |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | (unclear who by) | |
| Annese et al 2023 | N=1, male, ABI, TSI= 8 years | SCED | Use of own smartphone calendar and supplementary applications | Observational design | Analysis of phone and app data showed high use of calendar and consistent use with strategy to offload | Use of phone enabled pps to maintain high level of functioning and autonomy | None | United States |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | | cognitive tasks | | | |
| Bos et a., 2017 | N= 7, TBI, 100% male; Mean age= 51.5 yrs; moderate-severe TB (100%)I; TSI 2-19yrs | SCED | Smartphone with Google Calendar, email, to-do list, address book and keyboard applications | Pps trained for 4-8 hours during first 2 wks; Participant programmed reminders with cueing by researchers when not | EF & Memory | Pps showed variable task performance: >40% message task time improvement for 3 pps; 32%-71% message task content improvement for all pps | Pps trained for 4-8 hours during first 2 weeks (by researchers) | New Zealand |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | entered spontaneously | | | | |
| Chan et al., 2018 | N= 9; 5 TBI, 1 multiple sclerosis, 3 caregivers; Mage= 45; 3 male, 6 female; TSI (not reported) | SCED | "MyMemory" an app to support autobiographical memory and well-being | To complete daily memory tasks using app during two intervention phases, each lasting for two weeks | Memory | Descriptive statistics showed improvement in well-being, memory function, and autobiographical memory | Varied based on pps but included caregivers in some instances | New Zealand |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | | | No statistical analysis | | |
| Cruz et al., 2016 | N=2, TBI (100%), both male | SCED | Smartphone calendar and reminder | Utilised phones to send reminders over 3 months | Memory | Participant 1 showed improvements<br>Participant 2 showed some improvements | Taught in first review session how to utilise phone functions | Scotland |
| Ertas-Spantgar, 2022 | N= 4, 3 male, 1 female; TBI | SCED | Use of "RehaGoal App" on smartphone, micro- | 8-week intervention to achieve a | EF & Memory | All pps improved on goal attainment | 5 group training sessions accompanied | Germany |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
|  | (100%); TSI= 5 |  | prompting and setting goals | self-defined goal |  | SUS showed excellent usability | with homework (run by Psychologists) |  |
| Evald., 2014 | N= 13; 11 male (83%), 2 female; TBI (100%); TSI= 11 | Mixed methods | Electronic calendar on a smartphone | 6 week intervention with systematic memory strategies | Memory | No significant increase in target behaviours<br>A significant decline in self-reported prospective | 6 training sessions-1 individual and 5 group 1.5 hour sessions (by researcher) | Denmark |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | | | memory problems | | |
| Ferguson, Friedland, Woodberry, 2015 | N= 6 TBI, Age range 24-55; 83% male; TSI= 24.8 months (mean) | ABAB case series design (SCED) | Using own smartphone calendar and reminder functions | ABAB of reminder present and reminder absent phases | EF & Memory | Significant improvement in task completion rates when smartphone reminders provided | Practice evaluated over a week pre-intervention<br>Top up training given 10 days following intervention | UK |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| Jamieson et al., 2017 | N=3, TBI, 100% male, M age= 45.6 | SCED | Smartphone calendar and unsolicited prompts | Participants were given smartphones and asked to set daily reminders. Participants randomly allocated to unsolicited prompt phase for 2 weeks and to a non- | Memory | Mean increase for all participants in reminders set during unsolicited prompt phase | Training given but unclear how much (in part due to presence in a rehab unit) | Scotland |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | prompt 2 week phase | | | | |
| Jamieson et al., 2017 | N= 5; 1 male (20%), 4 female; TBI (100%); TSI= 13.1 | SCED | Use of "ApplTree" on smartphone; a calendar and reminding app | Tasked to set reminders using the app over 4 months. Pps received unsolicited prompts for at least 2 months and no prompts | Memory | Increased daily mean reminders set with unsolicited prompts<br>Ups (mean)- 0.63<br>NoUPs (mean)- 0.33 | Training given prior to intervention (unclear how much and who by) | Scotland |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | for at least 2 months | | No statistical analysis | | |
| Jamieson et al., 2022 | N= 29, 10 male, 19 female; M age= 47.3; 14 (65%) TBI, 15 other ABI (35%); TSI= 2; | Parallel randomized controlled feasibility trial | Pps used smartphone with either ApplTree; a smartphone reminder application, or google calendar on their phone (android/iOS) | Intervention session given followed by 6 weeks of independent app use | Memory | Highlighted pps did not require much learning to use the app<br>No significant change in baseline memory performance | Some training given prior to intervention (unclear) | Scotland |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| Ramirez-Hernandez et al., 2021 | N= 38, 21 male (55%), 17 female; M age= 61; TBI; TSI= 7.9 | Randomised controlled trial | Use of existing smartphone using "Cozi Family Organiser" app (no description of app provided) | Allocated randomly to 1 of 3 training conditions and trained over 1 2-hour session. | EF | No differences in training found at 6 weeks post training<br>Smartphone confidence increased 6 weeks post training | One two hour training session by Psychologists (registered) | Australia |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Self-reported memory complaints decreased across time across groups | | |
| Scullin et al., 2021 | N= 52, Gender unspecified, TBI (100%); TSI= unspecified | Parallel group trial design- RCT | Android phone and a reminder app (or digital recorder app | 4 week intervention to use device to support prospective memory | Memory | Pps reported improvements in daily reported prospective memory | Structured training in smartphones prior to intervention (unclear for | United States |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Pps performed well on prospective memory tasks (51.7% ± 27.8%), but reversing in favour the digital recorder app in week 4 (p= 0.010, ηp2=0.079) | how long and who by) | |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Use of ATC associated with better prospective memory performance | | |
| Vasquez et al., 2023 | N= 34, 26 male, 8 female; M age= 42.4; TBI, TSI= 5.3 | Retrospective chart review | Pps used either mobile phone or PDA and where trained in there devices mobile calendar to set alert notifications; then | Participants had followed training intervention; Phase 1; learning to operate | Memory | Smartphone devices required more training and tasks to complete to generalize the skills vs PDA’s | Guided practice with “trainers” during phase 1 | Canada |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | trained to generalise this skill. | digital calendar; phase 2; generalizing skills learnt in phase 1. Pps attended two 1-hour sessions per week, guided by trainers by practising 10 | | Initial training performance for responding to alerts was predictive of duration of phase 2 of program required<br>Pps with additional | | |

| Study | Sample | Study Design | Smartphone/ application Description | Intervention | Memory/EF support | Key Findings | External input | Country of Origin |
|---|---|---|---|---|---|---|---|---|
| | | | | trials per session | | executive deficits took significantly longer to complete phase 2 training | | |

Note. Sample characteristics and outcomes as reported by study authors.

Abbreviations: ATC= Assistive Technology for Cognition, TBI= Traumatic Brain Injury, TSI= Time Since Injury, SCED= Single Case Experimental Design, RCT= Randomised Controlled Trials, PDA= Personal Digital Assistant, EF= Executive Function, OT= Occupational Therapist

### 2.4.1. Sample characteristics

A total of 211 participants with brain injury were involved across the 14 studies assessed (M= 15; range: 1-52). The majority of studies recruited TBI participants, but Jamieson (2022) and Chan also used some ABI participants. Studies typically reported the severity of memory and EF impairments using neuropsychological assessments (e.g. Rivermead Behavioural Memory Test), although this was rarely an explicit eligibility criterion for participation. Several studies also included and recruited participants based on reported subjective memory complaints (Chang; Evald; Jamieson 2017; Jamieson 2022). A number also opportunistically recruited from clinics in which clinicians selected or put forward potential participants (Ertas-Spantgar; Cruz). The majority of studies reported time since injury (TSI), and involved participants 1+ years post-injury

### 2.4.2. Types of smartphone ATC

Most studies utilised participants' own smartphone devices, but Scullin provided Android phones for participants to use. Each study utilised some kind of electronic calendar, many utilising existing mobile phone calendars (such as Google calendar); although Ramirez and Scullin do not describe the apps used in detail, it is inferred they possess electronic calendars. Scullin also compared the "reminder app" to a voice recording app. Many evaluated the use of purpose-designed apps designed for people with cognitive impairments; 7 studies and 5 different apps.

### 2.4.3. Focus of smartphone intervention

Table 1 summarises participant's involvement in using smartphones in each intervention and the evidence of efficacy. Most studies trained participants to utilise an electronic calendar to record things they needed to do, which would then provide them "prompts" in the future. Two studies by Jamieson et al (2017; 2017) assessed whether "unsolicited prompts" (UP) set from the app (based on an algorithm) or set by researchers or clinicians affected the number of entries into electronic calendars

## 2.5. Discussion

*Narrative Synthesis Element 3: Exploring the Relationships within and between studies*

Following narrative synthesis of the included studies, three themes emerged from the data: 1) The Versatility of Smartphones to Support cognition; 2) Prospective memory support & Task execution, with two subthemes; Supporting Memory and EF, and supporting memory; 3) Training as a foundation.

### 2.5.1. Theme 1: The Versatility of Smartphones to Support Cognition

Smartphones possess numerous functions, but interventions assessed primarily focused on their electronic calendar functions. This feature served as a foundation for task reminders and memory aids for participants. However, there was significant variation in how electronic calendars were implemented across the studies, demonstrating both their adaptability and need for further tailoring beyond base features.

Several interventions utilised the native electronic calendars integrated into smartphones. For example, Cruz et al. (2016) employed Google Calendar to deliver SMS reminders to participants. This feature was also utilised by Bos et al. (2017) but was augmented by the installation of additional apps that synchronised to-do lists with the calendar. Their setup also prevented reminders from being "dismissed" until users confirmed they had completed it. These adaptations illustrate how what appears to be a basic calendar function within smartphones can be extended and adapted to meet the specific needs of TBI populations but likely require further adaptations. Scullin et al. (2021), in a slightly different approach, supplemented the calendars function with a voice recorder app to create memory memos. Over time, participants reported preferring the voice recording app over the use of calendar functions, underscoring how offering alternative tools to suit individual preferences can enhance the implementation of ATC.

Recognising the limitations of standard electronic calendar functionality, several studies circumvented these challenges by developing bespoke apps specifically designed to supporting cognition in TBI populations. For example, Jamieson et al. (2017) evaluated ForgetMeNot, a custom app incorporating an electronic calendar and unsolicited prompts (UPs), automated notifications that prompted participants to set reminders. Similarly, Jamieson et al. (2022) evaluated ApplTree. This bespoke app also utilised UP's, but with a more structured and guided process for entering reminders, aimed at reducing the cognitive load of doing so. Jamieson discussed how within this app further tailoring of the visual presentations was offered, such as a "narrow and deep" versus "broad and shallow" user interfaces, which could support the specific nature of impairments experienced by each participant. In making these technologies accessible, there was also some acknowledgment that some TBI survivors may be too impacted by cognitive deficits to take such central roles in the interventions. Ferguson et al. (2015) utilised reminders via email and smartphone calendars and pre-programmed reminders, which were formulated between caregivers, researchers, and participants. To this end, it highlights the extent to which these interventions can be further tailored and supported to incorporate parts of survivors' systems based on care needs.

Ertas-Spantgar et al., (2022) differed from other studies as they assessed how a bespoke app "RehaGoal" could be used to break tasks into manageable steps, and so linked memory support with goal-directed behaviour in a more focused way than other interventions. Notably, the extent to which it offered guidance was tailored to each user's specific rehabilitation goals. This differed from other intervention, as it did not use UP's or an electronic calendar but conceptually was similar to UP's given it incorporated elements of guided assistance.

Collectively, these results suggest that smartphones support memory and EF through two primary mechanisms: electronic calendars and prompts (both unsolicited and solicited). However, there is a clear need for tailoring these mechanisms to address the unique challenges faced by TBI survivors. The findings emphasise that the functionality built into smartphone is useful, but often insufficient, without this, necessitating the development of bespoke applications.

### 2.5.2. Theme 2: Prospective Memory Support & Task Execution

Assisting prospective memory was a primary focus across the reviewed studies. The efficacy of these interventions was evaluated using diverse methodologies, reflecting significant variability in both implementation and outcomes. Within this two sub-themes appeared: Supporting prospective memory and EF, and supporting memory.

#### 2.5.2.1. Sub-theme: Supporting memory and EF

Three studies evaluated interventions which supported both memory and EF, with varying degrees of efficacy and outcomes. Bos et al. (2017) conducted a single-case experimental design (SCED) that evaluated the use of Google Calendar enhanced with additional apps (N=7). Participants engaged in the intervention across six weeks, during which they received training and cues from researchers to enter reminders independently. The intervention yielded variable outcomes. All participants improved on task message content during the intervention, but this varied between 32-71% and by the end of the intervention, one participant showed a reduced task performance. Similarly, Ertas-Spantgar (2022) used RehaGoal, which combined memory support and goal-directed behaviour (N=4). RehaGoal involved the therapist and participants in identifying goals and then breaking those down into manageable steps within the app. Reminders were then set, and participants could follow the breakdown of tasks. On goal attainment, all participants improved, suggesting task execution (and therefore EF) was supported. The integration of reminders with task breakdowns appeared particularly effective, facilitating the translation of memory and supporting real-world goal achievement. Additionally, participants reported high levels of engagement with the apps, describing it as highly usable. Cruz et al. (2016) used Google Calendar to deliver SMS reminders to participants. The study aimed to support prospective memory and EF by encouraging participants to respond to reminders and notifications. While some improvements in memory tasks were observed, the study lacked robust evidence of broader impacts on EF or daily functioning. Additionally, the limited focus on participants' independent use of the technology reduced its overall effectiveness.

Vasquez et al. (2023) conducted a retrospective chart review (N=34) regarding calendar functions on smartphones and PDA's. Participants were trained to use these devices as diaries and to respond to alerts and notifications. While the primary focus was on memory support, the intervention also involved a degree of planning and task breakdown. The study found participants were generally able to learn how to use the ATCs and to generalise their use without external support. Unlike other studies, the outcome measures focused on the time required for participants to generalise these skills and found those participants with additional EF deficits took significantly longer to complete generalisation training. Ferguson et al. (2015) evaluated the use of smartphone-based reminders that were pre-programmed by researchers and caregivers (N=20). The intervention aimed to improve task completion and prospective memory through scheduled prompts delivered via email and calendar applications. Task performance improved significantly, particularly regarding task adherence and timely execution. However, the study relied heavily on caregiver and researcher input to program reminders, highlighting limitations in the independent use of ATCs, particularly for those with EF deficits.

#### 2.5.2.2. Sub-theme: Supporting Memory

Several studies focused on the use of bespoke applications to enhance memory performance, with mixed outcomes. Jamieson et al. (2022) conducted two evaluations of the app ApplTree, which utilised unsolicited prompts (UPs) to encourage participants to set daily reminders. In an RCT (N=29), six weeks of independent app use yielded no significant improvement in baseline memory performance, though participants provided positive qualitative feedback regarding usability (Jamieson et al., 2022). In a subsequent mixed-methods study (N=5), the delivery of four UPs per day doubled the number of reminders set by participants, indicating that UPs effectively promoted engagement. Similarly, Jamieson et al. (2017) evaluated the ForgetMeNot app in a single-case experimental design (SCED; N=3), finding that participants set more reminders during the two-week prompted phase compared to the non-prompted phase. However, they did not evaluate how UP's and reminders set transfer to task performance or goal-orientated outcomes.

In contrast, several interventions that relied on the existing functionality of reminders and calendars built into smartphones often produced modest or mixed results. Scullin et al. (2021) conducted an RCT (N=52) comparing the use of participants' own smartphones, utilising either electronic calendars or reminder apps, for prospective memory tasks. Over a four-week intervention, both groups reported improvements in prospective memory via daily questionnaires, and participants achieved moderate accuracy (51.7% ± 27.8%) on task-specific assessments. By the final week, participants showed a preference for a digital recorder app over the reminder app, citing greater usability. Similarly, Evald (2014) evaluated smartphone calendars in a six-week intervention for individuals with acquired brain injuries (ABI). While some participants demonstrated improvements in memory outcomes and task adherence, others showed little or no benefit, with variability attributed to differences in familiarity with smartphones and baseline motivation. Evald (2017) further investigated smartphone reminder systems, finding modest memory improvements with self-directed use, but outcomes varied significantly across participants.

The outcomes and efficacy of interventions varied, with some studies demonstrating clear improvements in memory performance while others showed limited impacts. Ramirez-Hernandez et al. (2021) evaluated the Cozi Family Organizer App, a tool with calendar and reminder functionalities, and found significant improvements in participants' proficiency with the app by the end of the intervention. This increase in app proficiency translated into more effective use of its memory-supporting features, suggesting that individuals with traumatic brain injury (TBI) can develop the skills needed to benefit from such technologies. In contrast, Cruz et al. (2016) used Google Calendar to deliver SMS reminders for task-specific memory support but found limited evidence of broader memory improvements or functional gains. While participants responded to reminders and demonstrated some improvements in memory tasks, the intervention's efficacy in fostering independent use and long-term benefits was minimal. These findings highlight that while these tools can lead to supportive outcomes in memory performance, simpler interventions like SMS reminders may lack the adaptability of more bespoke applications.

### 2.5.3. Theme 3: Training as a foundation

Training varied greatly across the studies and conceptually is important, particularly for participants who are less familiar with smartphones (likely older) and/or are more impaired. However, there was a general vagueness in which it was described.

Several studies incorporated structured training as a key component of their interventions. Bos et al. (2017) provided 4–6 hours of structured errorless learning over two weeks. This training focused on both specific memory aid functionalities and general smartphone use, resulting in significant improvements in participants' ability to adhere to task schedules and engage with the technology effectively. Similarly, Ramirez-Hernandez et al. (2021) utilised systematic instruction, including error-based learning and trial-and-error approaches, to train participants in using the Cozi Family Organizer App. By the end of the intervention, participants demonstrated increased proficiency with the app and improved memory task performance, suggesting the value of structured training for individuals with traumatic brain injury (TBI). Vasquez et al. (2023) took a progressive approach, with participants advancing from a training phase to an intervention phase only after demonstrating skill generalisation. The study found that participants with additional EF deficits required more extensive training and that baseline proficiency in responding to alerts predicted faster skill generalisation. These findings suggest that structured, personalised training tailored to individual capabilities and needs can significantly enhance intervention outcomes.

In contrast, several studies employed minimal or no structured training, leading to more mixed results. Evald (2017) provided only a single 1.5-hour initial session to familiarise participants with smartphone use, followed by group sessions focusing on technical support and compensatory memory strategies. This approach yielded modest improvements in memory performance, with significant variability across participants. The reliance on self-directed use, particularly for participants with limited familiarity or motivation, may have contributed to inconsistent outcomes. Similarly, Cruz et al. (2016) relied solely on SMS reminders delivered via Google Calendar without any formal training or user interaction. While the intervention facilitated task-specific memory support, it showed no evidence of broader impacts on memory functioning or user independence, highlighting the limitations of interventions lacking structured training components.

A few studies also assessed usability as part of their training and intervention design. Ertas-Spantgar et al. (2022) incorporated caregivers and clinicians into the intervention process, using the RehaGoal app to support participants with more severe cognitive impairments. This approach was successful, demonstrating that involving caregivers can enhance implementation and increase the utility of ATC's. By contrast, other studies, such as those by Jamieson et al. (2022) and Evald (2014), did not explicitly involve caregivers, leaving participants to navigate the interventions more independently. These findings suggest a potential importance of involving support systems, particularly for participants with greater impairments, for consistent engagement and positive outcomes.

### 2.6. Summary and Interpretation of Findings

The rapid development of research and technology in ATC necessitates ongoing evaluation, particularly for individuals with TBI, a population that is growing, significantly impacted, and often underserved in community settings. Smartphones, in particular, have demonstrated considerable potential to address the cognitive deficits associated with TBI, such as impairments in memory and EF. Despite anecdotal evidence of their utility from clinicians and TBI survivors, there is a clear need for continued synthesis and dissemination of findings to guide best practices and optimise the use of these technologies.

This narrative synthesis is the first to systematically explore the use of smartphone-based ATC in supporting memory and EF among TBI survivors. The findings align with previous research, confirming that smartphones can provide compensatory support for these deficits. However, the synthesis also identified significant variability in how these interventions are designed, implemented, and evaluated, underscoring the need for more standardised approaches to training and follow-up support. Effective training, sustained feedback, and ongoing user engagement are critical components of successful interventions, yet these elements were inconsistently described across the included studies.

Nevertheless, smartphones emerged as highly adaptable tools for cognitive support, with the majority of interventions utilising their electronic calendar functionalities. While standard smartphone calendars, such as Google Calendar, formed the basis for many interventions, bespoke adaptations, including Up's and tailored user interfaces, proved effective. In can be inferred that these adaptations reduced cognitive load, enhancing usability. Bespoke applications, such as ApplTree and ForgetMeNot, extended the capabilities of standard tools by integrating structured prompts and guided interfaces, facilitating greater task adherence and engagement. However, the efficacy of these interventions was likely influenced by participant preferences, baseline technological proficiency, and the extent of training provided, all of which were not controlled for.

Prospective memory support and EF enhancement were primary targets of the reviewed interventions. Studies such as those using RehaGoal demonstrated that integrating task breakdowns with reminder systems could effectively result in memory support and goal attainment. In contrast, interventions relying solely on standard calendar features or minimal training yielded more modest and inconsistent outcomes. The inclusion of caregivers and support systems further enhanced the usability and impact of interventions, particularly for participants with severe cognitive impairments, emphasising the importance of collaborative approaches in ATC implementation.

There was some evidence that training was important for intervention success. Structured training, such as errorless learning, was particularly effective in improving participants' ability to engage with ATC, especially for individuals with additional EF deficits. In contrast, interventions with limited or absent training demonstrated inconsistent results, suggesting the importance of training and ongoing support. These findings underscore the need for further research to establish standardised training protocols and explore how tailored technological features can maximise the utility of smartphones for TBI populations.

### 2.6.1. Quality assessment

*Assessing the robustness of the synthesis: Element 4*

Assessing the robustness of a narrative synthesis is a critical step in a narrative synthesis and can done by examining the methodological quality of included studies and situation the findings within the context of previous reviews (Arai et al., 2007). This synthesis, like previous reviews in this area, suffers from reviewing studies with significant methodological limitations. Of the 15 studies included, only four were RCT's. The remaining studies, predominantly single-case designs, demonstrated a relatively modest level of internal validity.

There were four Class I studies, 4 Class II studies and 6 Class III studies (See Appendix 8 and 9 for supplementary Table B and C). Alternative ATC's or memory strategies were involved as the comparator conditions in the class I studies. All four studies reported eligibility criteria, random allocation, between-groups analysis and point and variability measures. Jamieson et al., 2023 did not retain >85% of participants, with ten participants withdrawing from the study at baseline and seven more withdrawing at the three-week baseline phase and three more withdrawn by the research team because they could not be contacted during the baseline phase. In regards to the delivery of the AT intervention, only

Ramirez-Hernandez et al., 2021 evaluated treatment fidelity. None of the RCT's were able to blind participants or therapists within the interventions.

In the quality appraisal of the 9 single-case studies the mean ROBiN-T rating for internal validity was 3.13/14 (range: 1-5) and mean external validity rating was 8.5/16 (range: 6-12). The total mean rating was 11.6/30 (range: 8-14). All single-case studies assessed (100%) scored 1-2 for a sampling of behaviour, raw data record, data analysis, DV, and IV. Similar to the RCT's, most studies did not use blinding, assess interrater agreement, or report and examine treatment adherence, replication or generalisation. Of the 3 studies employing a design with a control two used an ABAB case series design (Ferguson et al. 2015; Chang et al., 2018;). One conducted a multiple baseline across target behaviour design (Cruz et al., 2016).

These findings are largely consistent with previous reviews. It is important, however, to consider why these patterns persist. Key, is the rapidly evolving nature of ATC's and technology. Smartphones and related software can undergo substantial changes even over the course of a single study, challenging the comparability and consistency of research conditions. Consequently, some degree of methodological inconsistency may be unavoidable across studies. Additionally, the prevalence of SCEDs reflects the inherent difficulty of recruiting large, homogeneous samples from a highly heterogeneous clinical population such as individuals with TBI. Nonetheless, there are opportunities for improving SCED quality. Adhering more closely to established methodological guidelines, such as those offered by Tate et al. (2013), and rigorously applying tools designed to assess SCED quality (e.g., the RobInt scale) from the earliest stages of study development could help enhance both the reliability and generalizability of future research.

# 3. Chapter three- Methods

This chapter outlines the methodological choices made for this study, beginning with the justification for employing a qualitative approach and, in particular, thematic analysis (TA). TA is adaptable and is uniquely well placed for this reason in how it can be used to align with the study's objectives and the researcher's critical realist perspective. The chapter will detail how the study was designed and implemented, addressing relevant quality and ethical considerations, concluding with a reflexive position statement from the researcher.

## 3.1. Rationale for study focus

The narrative literature search and synthesis, alongside prior exploration of the field in prior chapters, continues to highlight the potential of ATC to support cognitive functions following brain injury. However, it still remains unclear as to how useful, or even available, such tools are in clinical practice. It is also still unclear what makes an ATC intervention effective, whether it lies in design interface, training for users, external support, or something else. As highlighted in the narrative literature search, the focus on outcomes and efficacy in the literature is varied, and also largely in the short term, offering limited insights into clinical realities, including variability in usage and barriers to adoption.

Initial aims of this thesis were shaped by the dominant focus on memory and executive impairments following TBI. However, in light of the ambiguity in current research about how these technologies are actually used, this qualitative study was intentionally broadened to explore ATC’s more generally. This allowed for a more nuanced exploration of the range of technologies utilised by clinicians, which was likely to be smartphone based, but not limited to them, and the way in which these tools are embedded in neurorehabiliation practice.

### 3.2. Rationale for conducting a qualitative study

In clinical psychology, qualitative research has historically been marginalised and considered "soft" science when compared to the "hard" experimental approaches favoured in mainstream psychology. Traditional positivist approaches have dominated the field, promoting research that emphasise objectivity, measurement, and replicability as the cornerstones of scientific inquiry. Qualitative methods, by contrast, were often seen as supplementary, providing rich, descriptive accounts that were used primarily to support or explain findings from quantitative studies (Potter & Hepburn, 2005). More recently there has been a shift, and an increasing recognition that qualitative research offers unique insights into human behaviour and psychological phenomena not captured by quantitative approaches. More so, they may not be used in opposition but rather ask different and often complementary questions from which a greater understanding of human experience can be understood (Lyons, 2011).

The choice to select a qualitative methodology for this research was driven by the scope of the research question: What is the experience of clinicians implementing assistive technology for cognition? As this study seeks to understand the experiences of individual clinicians, it is necessary to explore the perspectives and experiences of clinicians in a way that recognises context (such as profession or service) and the subjectivity of their experience. The qualitative paradigm is well suited to understanding human behaviour and personal experience in ways that may not be possible with quantitative methods as it can provide an in-depth contextualised understanding (Bhati et al., 2013). Through its collection of rich, descriptive data, qualitative research seeks to understand participants through their frame of reference, which is consistent with the aims of the present study (Taylor et al., 2016).

Additionally, in line with social justice movements such as decolonising clinical psychology, qualitative research offers the flexibility to challenge dominant paradigms by valuing marginalised populations (Evans et al., 2014). This makes qualitative research well placed to champion social change and responsibility, whilst also aligning with the ethical responsibility of clinical psychology research to do so, whilst also generating knowledge. Qualitative methods have a rich history of being used in creative, critical, and decolonising methodologies, opening up pathways for research that is both socially responsible and attuned to the power dynamics involved in knowledge production (Gemignani et al., 2023).

A qualitative approach was therefore selected for this research to facilitate the collection of rich data, to gain an in depth understanding of the unique perspectives and experiences of clinicians working in the field of TBI that may be less accessible when utilising quantitative research design.

## 3.3. Thematic Analysis

### 3.3.1. Rationale for conducting a thematic analysis (TA)

The qualitative method chosen for this study is TA, an approach that enables the reseacher(s) develop, analyse, and report themes from qualitative data (Clarke & Braun, 2018). TA aligns well with the study's goals, focusing on understanding the experiences of clinical staff implementing assistive technology. This method is particularly suited to uncovering the facilitators, useful features, and barriers in using assistive technology, especially in a context involving a diverse population.

TA's suitability comes from its flexibility and ability to identify patterned responses or meanings within the data, which is crucial for identifying key elements related to the phenomena in question (Braun & Clarke, 2006). Given that clinicians working in TBI have varied experiences in services, profession and training the study seeks to identify common themes in experiences despite these variabilities. Thematic analysis is ideal for capturing any overarching themes. Additionally, epistemologically, TA is versatile. It can be integrated into numerous paradigms, including essentialist/realist and constructionist perspectives. This makes it particularly useful to apply to diverse phenomena and research questions.

TA's flexibility also extends to its capacity to operate at both semantic and latent levels of analysis. A semantic approach would look for the explicit meanings in the data, providing detailed descriptions and summaries of observed patterns. On the other hand, a latent approach delves deeper to uncover the underlying ideas, assumptions, and conceptualisations shaping the data (Boyatzis, 1998). Within a constructionist framework, TA aims to theorise the sociocultural contexts and structural conditions that shape individual accounts rather than focusing solely on individual motivations (Burr, 1995). Given that this research is interested in experience, to understand facilitators and barriers to successful ATC interventions, it will primarily utilise a semantic TA and, therefore, an essentialist/realist epistemology. However, the reality of coding and analysis means it is likely that some latent coding will occur as it impossible to be purely inductive, given that the researcher always brings something to the data (Terry et al., 2017). Therefore, this approach is particularly suitable for understanding the broader experiences mediating clinicians' use of assistive technology, as it seeks understand the practicalities of implementing assistive technology, but is still open to exploring the systemic and cultural influences on their experiences.

The potential use of interpretative phenomenological analysis (IPA) was considered but ultimately deemed less suitable. IPA, with its phenomenological focus, emphasises the subjective experiences of each participant, which would require the analysis of individual narratives rather than understanding broader phenomena (Eatough & Smith, 2017). Although IPA is effective in developing themes with less data and more intense analysis, its emphasis on personal worldviews would not provide the broader thematic understanding required for this study. In contrast, TA offers a better overall fit, capturing collective experiences and identifying dominant themes across various clinical contexts.

Thematic analysis was therefore chosen for its epistemological flexibility, its ability to perform multi-level analyses, and its suitability for identifying and interpreting patterns and themes in qualitative data.

### 3.3.2. Reflexive Thematic Analysis

Reflexive Thematic Analysis (RTA) is a distinctive approach within thematic analysis that emphasises the qualitative philosophy and flexibility in its procedures. As described by Braun and Clarke (2006), RTA highlights the importance of the researcher's reflexivity and subjectivity as valuable resources in the analytical process. Unlike coding reliability approaches, which are based on positivist assumptions and emphasise accuracy and reliability through structured codebooks and inter-rater reliability measures, RTA fully embraces the principles of qualitative research, allowing themes to develop from a fluid, iterative process of engaging with the data (Boyatzis, 1998; Braun & Clarke, 2019). RTA is particularly well-suited for research that aligns with experiential and critical perspectives. It supports both inductive and deductive approaches, acknowledging that theoretical assumptions always inform analysis, even in inductive methodologies (Braun & Clarke, 2013).

A core feature of RTA is its focus on the active role of the researcher in theme development. In this method, themes are not pre-existing entities to be discovered; they are co-constructed by the researcher through a deep engagement with the data (Braun & Clarke, 2019). This process includes immersion in the data, ongoing reflection, and iterative theme development and refinement. Themes are identified by and with the researcher. This makes reflexivity a critical component of RTA, recognising the influence of the researcher on the analysis. The continuous process of self-awareness and critical reflection on how the researcher's perspectives, values, and experiences shape the interpretation of the data (Braun & Clarke, 2019). Reflexive practice is a strength, enhancing the credibility and depth of the analysis by making transparent the subjective lens through which the data is viewed (Braun & Clarke, 2019).

The development of themes in RTA follows a six-phase process, as outlined by Braun and Clarke (2006). These phases are: familiarising with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. Each phase involves a recursive interaction between the data and emerging insights, allowing for continual refinement and deepening of the analysis (Braun & Clarke, 2013).

In RTA, codes are understood as the smallest units of analysis that capture significant aspects of the data relevant to the research question (Clarke & Braun, 2017). These codes act as the foundation for themes, which are larger patterns of meaning organised around a central concept. Again, the theme development process is dynamic, with the researcher continually revisiting and revising the data and codes to ensure that the final themes are coherent and meaningful (Braun & Clarke, 2019).

### 3.3.3. Coding

TA can be employed using either inductive or deductive methods. An inductive approach focuses heavily on the data itself (Clarke & Braun, 2015), where the coding process is not influenced by the researcher's pre-existing notions about the subject (Braun & Clarke, 2006). Conversely, a deductive approach involves analysing the data through the lens of established theories and concepts, making the analysis primarily data-driven but guided by pre-existing frameworks (Clarke & Braun, 2015).

For this study, an inductive approach was utilised. This method ensures that the themes generated emerge directly from the data rather than being shaped to fit pre-existing theories (Braun & Clarke, 2006). This approach is particularly advantageous when investigating areas that have not been extensively researched (Clarke & Braun, 2017).

### 3.3.4. Theme development

Following from the advice by Braun and Clarke (2013), the inductive approach was conducted at the semantic level, which is to say, the language and idiographic communication used to describe their experience was prioritised to privilege the perspective of the participants. Themes where identified at a deeper, latent level when the researcher deemed it essential to uncover the underlying meanings and assumptions within the data.

## 3.4. Ontology and epistemology

In research, particularly qualitative, the underlying ontological and epistemological assumptions play a crucial role in shaping the study's design, methodology and analysis. Ontology refers to the nature of reality and what can be known about it, while epistemology concerns the nature of knowledge and the ways in which it can be acquired. These philosophical positions are important to acknowledge, as they influence how researchers perceive and engage their subject of research, participants, and methods used to investigate them.

TA is well regarded for its theoretical flexibility and is not bound to a single theoretical framework (Braun & Clarke, 2006). It can be employed from any standpoint along the ontological continuum, encompassing the full range from relativism to realism. Both paradigms have faced criticism for being reductionist: relativism for viewing reality solely through the lens of human discourse and knowledge, and realism for committing the 'epistemic fallacy' by reducing ontology to epistemology (Fletcher, 2017).

### 3.4.1. Critical Realism

This research has been conducted from a critical realism (CR) approach, which has gained popularity as a useful philosophical framework in social scientific research and health research. A key pillar of CR is that ontology (i.e. the nature of reality) is not reducible to epistemology (i.e. our knowledge of reality). CR, therefore, deviates from positivism and constructivism by recognising there is more to "reality" than what can be empirically known and that reality is not just entirely constructed through and within human knowledge and discourse (Patomäki & Wight, 2000). CR describes a philosophy that combines realist ontology with a relativist epistemology and is theory-laden (but not determined). CR does not deny that there is a real social world we can attempt to understand or access through philosophy and social science, but some knowledge can be closer to reality than other knowledge (Danermark et al., 2002)

CR posits that "reality" is stratified across and into three interacting levels: empirical, actual, and real. The empirical level refers to events as we experience them; subjective reality where experienced and observable events can be measured and occur but are mediated through human experience. At the actual level, events occur whether or not we experience or interpret them, which often differ from what is experienced or observed at the empirical level (Danermark et al., 2002). The final level, the real level, causal mechanisms exist which produce events at the observable empirical level, but which are unobservable social structures.

The aim of CR is to explain social events through reference to these causal mechanisms. It assumes that those social, causal, unobservable mechanisms inherent within social phenomena can be known through efforts to understand the observable empirical level. This research was approached from a CR perspective, permitting the researcher to develop a patterning of participants' experiences of implementing assistive technology for cognition, in a way that has relevance for how they are delivered in ABI populations.

### 3.4.2. Implications for research

Applying CR to research in Clinical Psychology, in itself implies a nuanced approach to understanding the implementation of assistive technology for cognition. CR states there are both subjective and objective experiences inherent in the area which also exist independent of our perceptions. Nevertheless, it also posits that how we understand and make sense of this is mediated by social, cultural, and personal frameworks. Acknowledging this "layered" approach recognises that often unseen factors such as organisational policies and clinician attitudes are important in determining the experiences of implementing assistive technology. CR also implies a causal focus to research which will help the research move beyond surface-level observations, and begin to unpick the key contributors to effective implementation of assistive technology.

## 3.5. Method

### 3.5.1. Design

This study used a qualitative, semi-structured interview-based design, drawing upon a critical realist ontological and epistemological assumptions to investigate the experiences of clinicians working in TBI rehabilitation using assistive technology for cognition, emphasising facilitating factors and barriers.

### 3.5.2. Participant Recruitment

This study was initially conducted in conjunction with an existing service evaluation project at St George's University Hospitals NHS Foundation Trust. A purposive sampling method was employed, targeting clinicians working within this NHS Trust. However, due to insufficient recruitment from this pool, the recruitment scope was expanded to include other services. As the study was also linked to Neumind, the organisation facilitated contact with a number of clinicians who had previously expressed interest in participating in research.

Additionally, snowball sampling was utilised to further increase the number of potential participants by encouraging existing participants to refer colleagues.

Clinicians were contacted via email, inviting them to express interest in the study. Inclusion criteria were applied to ensure participants met the necessary qualifications (Table 2).

The inclusion criteria were deliberately broad, encompassing both qualified and unqualified clinicians across a range of professions. This was motivated by pragmatism, to facilitate the recruitment process by widening the eligible participant pool. It also had the added benefit of supporting the capture of more diverse experiences from clinicians. However, to ensure adequate experience in neurorehabiliation, participants were required to have a minimum of six months of relevant work experience before being interviewed.

### 3.5.3. Inclusion criteria

**Table 2**

*Participant inclusion criteria for study*

| |
|---|
| English speaker |
| Working or having worked in ABI |
| Some experience utilising assistive technology for cognition clinically |
| Minimum of 6 months experience working in neurorehabiliation |

### 3.5.4. Participants

12 participants were recruited to the study. The number of participants required for qualitative research, and specifically TA, is contested. Braun & Clarke (2013) have suggested quality of the data, scope of the research, study design all affect how much data is required. They also suggest that when exploring "experience" a small/moderate sample is required.

The concept of "saturation" has been commonly used in qualitative research to justify the number of participants. Despite its wide use, it has been scrutinised as poorly operationalised and variably implemented, and therefore imprecisely used and under-questioned as a "gold standard" for qualitative inquiry (Braun & Clarke, 2021). Several reviews have indicated that qualitative researchers demonstrated a low level of transparency regarding sample size and justification for them (Carlsen & Glenton, 2011). It is often the case that the authors claim that saturation was achieved without specifying how it was assessed.

In recognition of the controversy of utilising saturation, the sample size was guided by information power, a concept and model set out by Malterud et al., (2016). Information power is an alternative to data saturation and summarises that the more relevant information a sample holds, the fewer participants are needed. This has been concluded as a useful alternative to data saturation, both in actuality and pragmatically (Braun & Clarke, 2021). The model states that the size of a sample with sufficient information power depends on a) the aim of the study, b) sample specificity, c) the use of established theory, d) quality of dialogue, and e) analysis strategy. Based on these criteria, the sample size of 12 was determined to be an adequate sample size for the following reasons: this study's aims were primarily regarding a) clinicians' experience, b) where purposively sampled from neurorehabilitation backgrounds, c) had an inductive approach, d) transcripts were of generally very rich quality, e) this was a case analysis strategy and therefore requiring in-depth analysis of narratives from fewer participants. Individual participant demographics are detailed in Table 3.

### 3.5.5. Materials

Microsoft Teams was used to conduct all interviews. It is a secure video-calling service that also offers a recording and transcription (auto-generated) function. Transcripts were manually revised while listening to the recordings to check the quality and offer further in-depth acquaintance with the material. This was done using guidelines from Bailey (2008) for audible talk, with consideration given to the specificity of the language and culture.

Transcripts were imported into the specialist data management software program, Nvivo, to conduct the process of coding.

### 3.5.6. Interviews

Semi-structured interviews were conducted. Semi-structured interviews are commonly utilised in health research, offering enough structure that enable predetermined questions whilst ensuring the participants are able to discuss issues that they feel are important and/or arise naturally (Gerrish & Lacey, 2010).

The semi-structured interview (see Appendix 5) was developed through informal discussion with supervisors and informed by the literature. Questions were designed to be open-ended and exploratory, encouraging reflection on practical and experiential aspects of ACT implementation. The interview was produced in conduction with the study aims, and whilst no substantial changes were made following ethical approval, minor iterative adjustments to question phrasing or follow-up prompts were made following early interviews to improve clarity and flow.

Focus groups were considered for this research study and are closely related to interviews. Focus groups can be useful in healthcare research, providing an effective means to collect perspectives, attitudes, and experiences. However, the practicalities and complexities of conducting focus groups made them a less attractive option. For example, given the nature of the participant pool; clinicians working in healthcare, many work long and variable hours, and as such, co-ordinating a big enough focus group would have been challenging. There are also challenges of power dynamics within such group interviews, e.g if a clinical psychologist was present with an assistant psychologist that may influence the ability of other members of the group to talk freely and share experiences, disagree and so forth. The research also is not centrally focused on how multiple disciplinary teams (MDT's) interact.

In summary, the practical and methodological alignment of employing interviews rather than organising focus groups outweighed the potential benefits of conducting focus groups for this research study.

#### 3.5.7. Procedure

Once participants had expressed interest in participating in the study, and had been assessed as eligible, they were sent an information sheet and consent sheet (Appendix 2 and 3) and invited to ask any additional questions. Interviews were then arranged at a mutually convenient time.

### 3.6. Data Analysis

*The six-phase analytical process*

Braun & Clarke (2020) describe a six-phase process of conducting a reflexive thematic analysis. This approach, and Braun & Clarke's (2013) system for transcription notation where adopted to increase transparency and adopt a structured approach. The researcher reviewed the automatically transcribed Microsoft Team interviews and edited them to follow this system. This further aided immersion in the data to become more accustomed to its breadth and depth. This aided fluidity of movement from different points, facilitating the process of comparison (Morrow, 2005).  This "frame" is generally followed in the literature of thematic analysis. However, as they describe, this is not a linear process, although it is normally described in a logical sequential order. Nevertheless, the research is still required to recognise this and be cognisant that the analysis is recursive, iterative, and moves back and forth through those phases where necessary (Braun & Clarke, 2020). This is a valuable part of the process as it can lead to interpretations that were not immediately evident. To this end, Braun & Clarke's process is a guideline that should be applied flexibly (Braun & Clarke, 2020).

### *Phase one: Familiarisation*

"Familiarisation" is not a unique phase of data analysis to thematic analysis, and is prevalent in many forms of qualitative analysis. It is a valuable data analysis stage, entailing the reading and re-reading of collected data to immerse the research in the data. Interviews should be transcribed by the researcher to aid this and include orthographic information, such as breaks, pauses, and tone, on both the part of the interview and the participant (Braun & Clarke, 2013). However, it is not irregular for research interviews to be conducted and collected by secondary researchers or using electronic software, in which it is helpful for the researcher to watch and listen to those video/audio recordings to facilitate this first step of the RTA. Whichever way this is done, it is a time-consuming process, requiring patience and significant time protection to conduct adequately.

During this phase, the researcher listened to each interview recording. During the first playback, they did not take notes or review the transcripts but rather "actively listened," considering the content of the interviews and their reactions to them. Each interview was listened for a second time, immediately after the first, whilst also reading through the transcripts that Microsoft Teams had generated. During this stage, the researcher edited and noted orthographic information. Once all of the interviews had been fully transcribed, each transcript was read numerous times. At this point, common points of interest were already emerging from the data, and passages of transcripts that appeared particularly rich were also noted. The researcher also took the time to document the thoughts and feelings that were provoked during this process, which is recommended when conducting an RTA.

The coding was conducted using Nvivo, a coding software designed for this process that allows for codes to be noted in an optional side margin and highlights the text assigned to each respective code. This allows for both an ease of coding experience, without overlap or double-codes, and collates the number of each code and records which areas of text correspond to each code.

It is generally advised to "over-code" rather than be restrictive with coding, as codes can and are reviewed and refined later in the RTA process (Braun & Clarke, 2013). To this end, any item of data that appears to have some relevance to the research question(s) should be coded. Through further immersion in the data and the analysis, codes conducive to generating themes can be kept and others discarded.

### *Phase three: generating themes*

Once the data has been coded, this phase might be thought as formally beginning, although it is likely emerging themes are already apparent and being considered. The coded data is reviewed and analysed to consider which codes can be combined based on shared meanings to begin the formation of themes and sub-themes. Multiple codes may be collapsed together if they share enough overlap, and indeed, codes can themselves become themes if they represent enough of an over-arching narrative within the data (Braun & Clarke, 2012). During this phase in particular, the reflexive nature of the RTA is evident, given the researcher is actively construing relationships among the codes, and "creates" meaning via an inductive process to find something meaningful relating to the research questions (Byrne, 2022).

It is important that themes are distinctive and relate to each other, even if they are contradictory, creating a coherent and lucid picture of the data. Numerous prospective themes may be produced, and it is important to refine and let go of those that do not fit the criteria. If this is not done, the analysis may become incoherent and confusing, whereas too few may produce an analysis lacking depth, reflecting a surface-level understanding of the data. It is advised to begin collating themes together in a visual construction, such as in a thematic map (Braun & Clarke, 2012).

### *Phase four: reviewing potential themes*

In this phase potential themes are reviewed, and contextualised in regards to the data and research question (Braun & Clarke, 2020). If the codes that inform the generation of the themes or the themes themselves do not function well as meaningful interpretations of the data, it is necessary to review and refine them. Braun & Clarke (2012, p. 65) propose a series of questions researchers can use to help review prospective themes. These will be described below with examples:

- *Is this a theme (it could be just a code)?*

For example, the theme “Make it unique (or don’t bother)” is decidedly a theme. Personalisation of ATC’s could be captured as a code (e.g. “Personalisation), but this theme captures more than description, by addressing how and why personalisation occurs.

- *If it is a theme, what is the quality of this theme (does it tell me something useful about the data set and my research question)?*

This theme addresses the research question on how clinicians' experience implementing ATC interventions, that the technology is not enough; it's success depends on adaptation and integration into the user's lives.

- *What are the boundaries of this theme (what does it include and exclude)?*

This theme includes the act of modifying and selecting ATC's, and trial and error, whilst recognising the wider systems surrounding clients. It excludes more general issues such as funding, or training.

- *Are there enough (meaningful) data to support this theme (is the theme thin or thick)?*

There are multiple codes captured within this theme, and discussed by participants throughout, and emerged organically from the data. It is therefore "thick".

- *Are the data too diverse and wide ranging (does the theme lack coherence)?*

The central concept of personalisation ties the theme together, providing boundaries, but within that concept there are varying perspective privileged in the data. As such, sub-themes are required to keep this theme coherent.

These questions were used to shape the theme development whilst exploring the codes generated during the previous phases.

### *Phase five: defining and naming themes*

During this phase, the prospective themes are further refined and defined. Each theme needs to communicate and capture information not told by other themes in a coherent and consistent way (Patton, 1990). The themes should combine to create a narrative that ultimately makes sense of the research question and data.

The final naming of the themes is also finally reviewed, which is an important task; given names are the first communication from the researcher to the reader about what has been captured and analysed from the data. A trap that researchers can fall into is creating descriptive names for themes. However, it is encouraged to use creativity and the use of "catchy" names that capture the attention of the reader whilst communicating something of importance and value (Braun & Clarke, 2020).

*Phase six: producing the report*

This "final" phase is described as the end of guidelines set out by Braun & Clarke, but rarely does it occur cleanly at the end of the analysis. Writing and reporting qualitative research interweaves analysis and write-up (Braun & Clarke, 2012) and, by its very nature, is a recursive process.

## 3.7. Ethical Considerations

The present study evaluated a number of ethical issues, but was generally deemed to be ethically sound. However, the act of providing care within a healthcare system such as the NHS can invoke emotive reactions in all clinicians. Whilst it was deemed unlikely the interviews would become distressing, there was the potential for challenging experiences or feelings to arise. This was to be made clear prior to participants giving their consent. It was emphasised to participants that they do not have to participate in the research and they can stop the interview at any time without needing to explain why. Participants were also advised that they can withdraw their consent for their data to be used in the study up to one week after the interview is completed. Prior to conducting the interview, information about the NHS staff wellbeing team was also provided to offer participants support if they experience distress following or during the interview. This study received approval from the University of Essex Research Ethics Sub-Committee 2.

### 3.8. Quality

Braun & Clarke (2020) describe a "snappy" 10 set questions to ensure the rigour of TA methodology and, therefore, the quality of the data set generated and analysed. A strong and nuanced understanding of the context and underlying principles of thematic analysis is important in generating higher-quality research. This study has been developed using these questions to evaluate the research quality of the RTA and maintain and ensure a high-quality analysis and research design.

Given that this is an RTA, its quality can be further constructed and enhanced through the active process of reflexivity by recognising how the researchers' influence on the project and their interpretive framework affect the research (Clarke & Braun, 2018). This helps both the researcher and reader better access the research and better understand the researcher's biases and motivations.

### 3.9. Reflexivity

This research has taken an inductive approach to the analysis, which is to say, it was bottom-up and driven by the data. Nevertheless, a purely inductive approach is impossible, given my experiences as a researcher and clinician will influence the way I collect and interpret the data. It is therefore important to acknowledge that I, as the researcher, will influence the analysis of the study and therefore its direction and outcomes, given my beliefs about the interviews, the topic, and wider context of TBI. During the interviews, of which I carried out, I was conscious about the need to gain "good" data for my professional doctorate and indeed, that there was a strong indications that assistive technology can and is useful in this area of work. To this end, it was important to as best as possible compartmentalise these thoughts and feelings to ensure I did not overly influence participants' responses (Anderson, 2010). In an effort to do so, I did not hold to my semi-structured interview questions too firmly and tried as best I could to notice when participants wished to deviate and bring in adjacent or separate topics by being curious with them about their experiences. Nevertheless, it is without question that how the interviews were conducted was influenced by my written questions, how they were asked, how I responded to answers, and how I followed up what was disclosed by participants.

# 4. Chapter Four- Results

This researches initial intention was to recruit clinicians from an inpatient neurorehabilitation service that had been linked up with as part of an existing service evaluation. However, this research was unable to recruit sufficient numbers from that service, and as such, opened the recruitment to include clinicians from other services. The recruitment of participants was, therefore, more difficult than anticipated, as many therapists did not respond to the invitation to take part, including those who initially expressed an interest in being involved but could not follow through with that interest. Faced with these challenges, it was ultimately decided that expanding the recruitment criteria would be a pragmatic solution to this difficulty, provided that the data obtained from therapists remained rich and aligned with the research aims.

To recruit potential participants, the researcher accessed records from Neumind, a company designing an app to support cognition in people with TBI, who they had initially begun working with in line with the initial inception of this research. Whilst the research did not directly involve them in its final form, they did provide the researcher with a list of clinicians they had previously worked with, who had consented to be contacted for future research opportunities. Using this data set the researcher was able to contact those clinicians via email, with an overview of the project and an invitation to take part. If they responded with interest, they were corresponded with via email, and a Microsoft Teams meeting was organised following the receipt of consent.

## 4.1. Outcome of recruitment

The recruitment and intervening phase took place between June 2024 and November 2024. This period was relatively brief, which was a consequence of time pressures regarding the researcher's clinical psychology training course and the changes in the research questions (which will be discussed in more detail in the discussion chapter). In total 12 interviews were conducted, and data was analysed from all 12 of these.

**Table 3**

*Participant information*

| Participant | Profession | Service | Ethnicity | Gender | Country | Level of experience in neuro (years) |
|---|---|---|---|---|---|---|
| 1. P1 | Assistant Psychologist | NHS | White | Female | UK | +1 |
| 2. P2 | Clinical Psychologist | NHS | White | Female | UK | +10 |
| 3. P3 | Clinical Psychologist | NHS | White | Female | UK | +13 |
| 4. P4 | Assistant Psychologist | NHS | White | Female | UK | +2 |
| 5. P5 | Occupational therapist | NHS | White | Female | UK | +8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6. | P6 | Case worker-Occupational therapist | Private | White | Female | UK | +11 |
| 7. | P7 | Councillor | Private | White | Male | USA | +15 |
| 8. | P8 | Neuropsychologist | Private | White | Male | USA | +25 |
| 9. | P9 | Occupational therapist | Private | White | Female | USA | +4 |
| 10. | P10 | Speech and Language Therapist | Private | South Asian | Female | USA | +6 |
| 11. | P11 | Occupational therapist | Private | White | Female | USA | +6 |
| 12. | P12 | Assistant Psychologist | Private | White | Female | UK | |

#### 4.1.1. The interviews

All of the interviews were conducted by the researcher and lasted around 40-60 minutes. They were conducted via Microsoft Teams at a time mutually convenient for the participant and researcher. Online interviewing is still a relatively recent mainstream research approach but has been found to be equally as rich and valuable as in-person interviews (O'Connor et al., 2008). All interviews were audio-recorded and transcribed using Microsoft Teams (see Appendices 6 for an extract of an interview and coding).

Prior to starting each interview, participants were given an overview of the purpose of their research and given a chance to discuss any questions or issues, which doubled as another chance to check consent. All participants were happy to participate, so interviews were conducted, following a semi-structured questionnaire as a prompt, which had the benefit of offering the researcher prompts as the interviewer but allowed for a non-directive style of interview, which gave participants space to outline and reflect on their experiences organically.

### 4.1.2. Reflexive statement- The researchers experience of the interviews

I found conducting the interviews engaging and interesting, noting that different professions sparked different ideas and developed my understanding and consideration of the topics of discussion. This then influenced what I brought to the next interview, as well as noticing commonalities in themes and topics across multiple interviews, articulated both consciously and unconsciously by participants. It was clear very early on that assistive technology is being used more so than is evident in both the literature, and by clinicians (in which multiple participants acknowledged explicitly). I began to develop a complex picture of what is important in implementing assistive technology successfully and what things get in the way of a successful and long-term implementation.

In an effort to be both transparent and collaborative, I was open about my own position regarding the topic and research; that I have an interest in technology and the field of neurorehabilitation, but that the research is also personally and professionally important to me within the context of completing my doctorate in clinical psychology. At times, I disclosed that I had personally some experience working in this area, with technology, and that I had also found some things worked and did not work, but that as part of working as a reflexive practitioner, I recognised that there was much I did not know. I also recognised that my experience in the field was predominantly from a number of years ago, and that this area will have progressed so much since then. I endeavoured to use these disclosures carefully and minimally to help develop rapport whilst also balancing the research participant hierarchy, and I  felt it stimulated discussion, allowing participants to express a range of experiences, good and bad (Braun & Clarke, 2014). More often, participants came to the interview feeling as though they did not have much experience in this area. However, through discussion, it became evident they did, and they had many views on what was useful and what wasn't and where gaps existed in the research and clinical practice.

I also tried to notice in myself, during interviews and afterwards, topics I wanted to bring up and discuss. In particular, issues of diversity and inclusion, which I feel strongly about, and is particularly relevant within the field of clinical psychology, and often lacking from research. Nevertheless, I felt that bringing these topics into the interviews risked being too leading, mainly due to my own bias and interest, and as such, I stuck to more open-ended questions. I was pleased that these topics still arose in interviews, although some consideration as to whether my own unconscious bias predisposed them to come up in conversation is something to consider. On this topic, it was also noticed that the interviews for many participants appeared to be a reflective and positive exercise, allowing them to process and reflect on their experiences. One clinician following it emailed their assistant psychologist, suggesting they participate, partly due to the value of reflecting on their experiences. Indeed, this is a phenomenon that is refreshed in the literature: that interviews can provide positive experiences and benefit participants (Braun & Clarke, 2014).

## 4.2. Findings

The RTA's findings will begin by providing an introduction to the participants. This will be followed by a thematic map as a visual guide to the main themes and sub-themes and their connections. Each theme will then be described and discussed in detail. Example quotes from participants within a table of themes will also be presented.

*Presentation of findings*

Throughout the results, participants will be referred to via pseudonyms as P1 or P2, and so forth. When quoting participants directly, ellipsis within square brackets will be used when any words have been left out of the original quote (e.g. […]). Where a particular word was emphasised it will be quoted in italics.

*Introduction to participants*

The participants in this study ranged in profession but were predominantly Clinical Psychologists and assistant psychologists. However, Speech and Language therapists (SALT), Occupational therapists (OT), and a councillor were also recruited. Of the participants, the vast majority were female (84%). All participants had 1+ years of experience working in neurorehabilitation up to 25+ years.

## 4.3. Overview of themes

Through the six step process of conducting a RTA as described above, five themes where developed in relation to the research questions:

<u>Theme one: Technology is diffuse</u>

*Subtheme one: Complexity and usability of technology*

*Subtheme two: Barriers to access*

<u>Theme two: Make it unique (or don’t bother)</u>

*Subtheme one: Push where it moves*

*Subtheme two: Training smartly*

<u>Theme three: Context matters</u>

*Subtheme one: MDT working*

*Subtheme two: Service matters*

*Subtheme three: A family issue*

<u>Theme four: Professionals bring themselves</u>

*Subtheme one: Comfort with technology*

*Subtheme two: The therapeutic relationship*

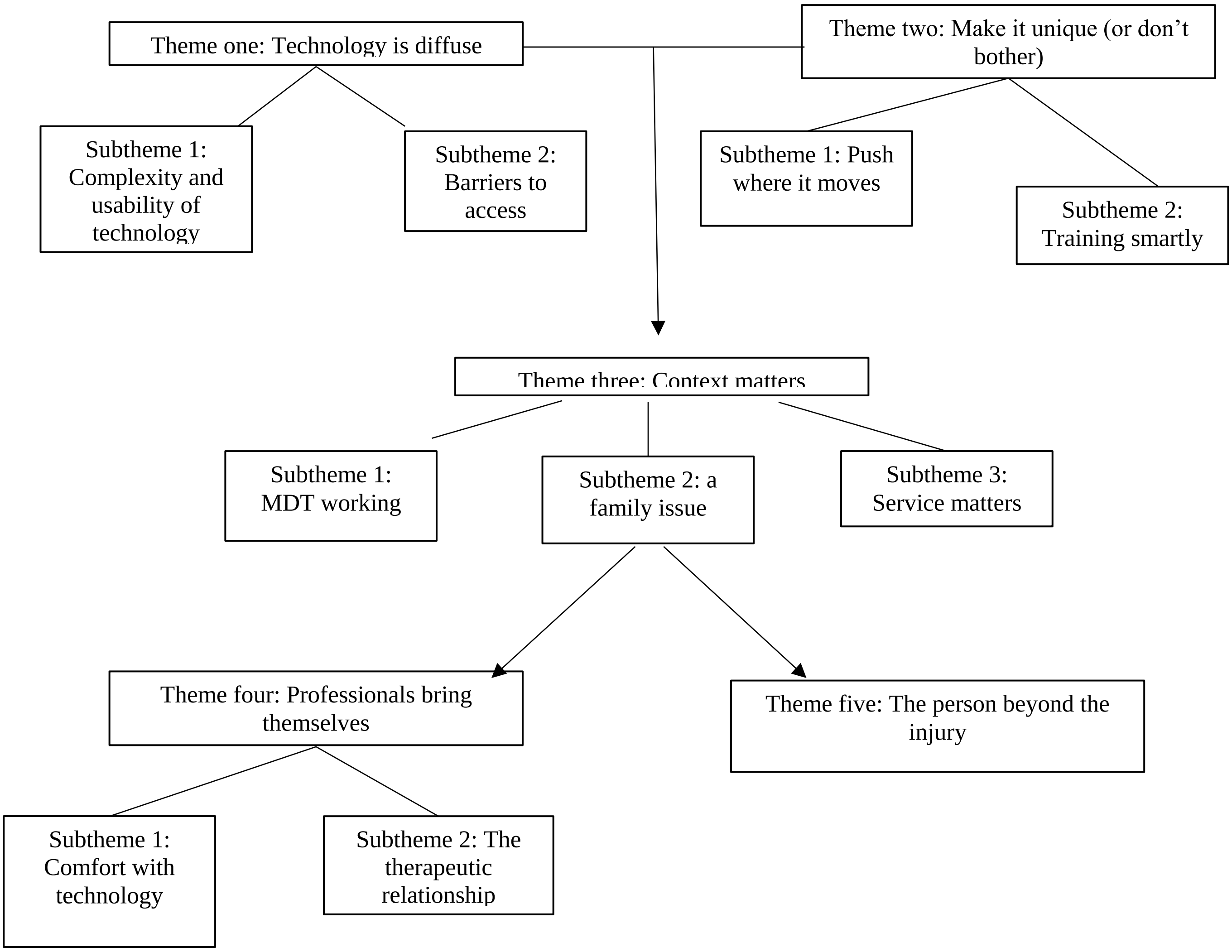
<u>Theme five: The person beyond the injury</u>

The order of themes reflects how they emerged through the analytic process, progressing from practical considerations (primarily semantic analysis) to systemic factors (a mix of semantic and latent analysis) and finally to relational aspects (primarily latent analysis).

The first two themes came from predominantly semantic analysis, capturing how participants described the availability, implementation, and adaptability of assistive technology for cognition (ATC). These themes focused on pragmatic concerns, reflecting what participants explicitly said about their experiences of implementing ATCs. The third theme acts as a bridge between these practical themes and the more interpretative, relational themes that follow. While participants spoke directly about funding, healthcare systems, and MDT structures, there was also a latent dimension, particularly in how systemic constraints shaped decision-making and intervention delivery. This theme reflects both structural factors and more implicit influences that were harder for participants to articulate but still shaped practice. The final two themes required greater latent analysis. While participants discussed their professional identities and relationships with clients, the significance of these narratives became clearer through a reflexive lens. The researcher's own experiences working as a clinician will have particularly influenced this level of analysis and is discussed at the end of the chapter.

**Figure 3**

*Thematic map showing themes, subthemes and their interconnections*



## 4.4. Theme one: Technology is diffuse

*"You know there are over 100 speech and language therapy apps out there. So which one?"*- P10

This theme highlights the ubiquitous yet paradoxical nature of technology when applied to ATC and neurorehabilitation. Almost every patient has a mobile phone (at least), and the diversity of tools on offer to both patients and clinicians has never been greater, offering flexibility and choice. However, it also introduces complexity, uncertainty, and challenges in establishing what to use against a backdrop of a lack of clear guidelines. The ready avaialbility of technology, both clinical and mainstream, can empower clinicians and those they support, but also make decision-making complex. These difficulties are further compounded by systemic and social barriers, as well as gaps in service provision, which hinder consistent application. Two subthemes were identified within this theme: Complexity and usability of technology; and Barriers to access.

### 4.4.1. Theme 1, Subtheme 1: Complexity and usability of technology

Participants consistently emphasised the challenges posed by the complexity of ATCs. While the vast array of functionalities and tools available was seen as a strength, it often created confusion about which technologies to use, when, and for whom. This complexity was further compounded by the mismatch between mainstream technologies, such as smartphones and readily available apps, and the unique needs of individuals with cognitive impairments. As P3 stated, *"[…the very basic elements of the platforms themselves, they need to be simpler to use.]"*.

This spoke to the most commonly utilised technologies, mainstream smartphones, which are affordable and commonplace. However, they are not typically designed for individuals with brain injuries, leaving therapists and clinicians to adapt these technologies for rehabilitation purposes. This process was described as inherently difficult and often frustrating. For instance, one participant noted, *"I haven't been able to find a good app that enables people to record their fatigue successfully [...] across a 24-hour period"* (P3). This highlights a critical gap in functionality: while ATCs hold potential, they frequently lack the adaptability or precision to meet specific therapeutic goals. Another participant observed, "So it's all usually down to the cell phone and trying to make that work" (P8), underscoring how participants, when attempting to rely on ATC's, rely on smartphones, which are imperfect despite their powerful functionality.

The rapid pace of technological advancement was another issue raised by participants. Those with extensive experience in neurorehabilitation reflected on how technology has changed over time in the clinical setting. While these advancements were often described positively, they also created challenges in maintaining familiarity with new developments and ensuring their relevance in practice. P1 illustrated this by stating, *"[…I know in like two years Google Drive will have this on here as an option"*, when discussing Google calendar lacking adaptability. This also illustrated the continual lag between technological innovation and its application in clinical practice; it could potentially have a more significant role in neurorehabilitation but continues not to be fully realised.

Participants also described when searching for apps that there was an oversaturation, many of which offered similar functionalities with varying degrees of use. This "crowding" effect made it difficult to identify the most appropriate tools for clients. One participant reflected on this saturation, saying, *"There's a boatload of apps out there, right?"* (P8). This abundance often led to redundancy and inefficiency, creating additional layers of complexity for clinicians attempting to navigate the options. There was a strong desire among participants for more streamlined solutions. As P7 articulated, *"The phone puts everything in one place, but it contains multiple steps. If there was one app where everything could be, that might be helpful".* This quote highlights a key issue: while smartphones contain multiple functions, they often require complex, multi-step processes that can be overwhelming for clients with cognitive impairments, making their application less straightforward than may be initially apparent.

Despite these challenges, participants consistently recognised the potential of ATCs. There was a sense of optimism that, with appropriate development and research, these technologies could significantly enhance neurorehabiliation.

### 4.4.2. Theme one, subtheme two: Barriers to access

In addition to the complexities of usability, participants identified significant barriers to accessing ATCs. These barriers were tied to systemic, social, and financial factors, which often intersected to limit the adoption and effectiveness of ATCs in neurorehabilitation.

The most consistent barrier was the financial burden associated with ATCs. Participants noted that clients were often required to fund apps or trials due to limited support from health systems, such as the NHS or insurance providers. This created inequities in access, particularly for individuals with moderate cognitive impairments who did not qualify for funding but still required support. As P10 explained, *"But literally, I've had patients who say, like, I don't even have $50 to, like, make it to this session. So just what can you do for me?"*. This also compounded clients' ability to access smartphones or reliable internet connections despite the ubiquitous nature of both in the modern day. A number of participants acknowledged that broader social inequities must be considered regarding the implementation of ATCs.

*"It's not just about the app. It's about whether they even have the resources to use it in the first place."* P5

Financial barriers also affected participant's familiarity with ATCs. Without sufficient funding, clinicians were less likely to trial apps or integrate them into their practice, contributing to a lack of awareness and confidence in their use. This created a self-perpetuating cycle: limited funding reduced exposure to ATCs, which in turn limited their adoption and slowed their integration into clinical services. In tandem, participants highlighted these systemic issues as a lack of general investment in neurorehabilitation, which impacted ATC's adoption. This was described as being a particular challenge in healthcare systems like the NHS, where funding constraints and bureaucratic hurdles limited the consistent dissemination of neurorehabilitation and ATC's.

*"It's so hard to get hold of specialised apps or devices"* P3 (NHS)

This further hindered the broader development and adoption of ATCs in neurorehabiliation. It was felt that the lack of systemic support and investment perpetuated a cycle in which the limited availability of ATC's discouraged research, and clinical adoption, further slowing progress. As P6 summarised *"[...we're always looking at using technology to compensate, but it just feels like there isn't enough out there yet]"*.

Yet, in a contradictory way, participants also observed that there was a saturation regarding apps to choose from, including those specifically to support certain functions. With so many options available, it was difficult to know which apps were genuinely effective, and this ambiguity often deterred both clients and participants (and other clinicians) from adopting technology. P8 noted *"You see apps claiming to do everything, but it's hard to know which one actually works, and that's a risk for us and for the clients".*

## 4.5. Theme 2: Make it unique (or don't bother)

This theme reflected clinicians' efforts to align ATC's with survivor's lived experiences, emphasising interventions that "make sense", which is to say, identifying and implementing strategies that take into account each individuals current functional abilities, prior experiences, and personal goals. Rather than imposing standardised interventions, participants highlighted the importance of ensuring that any introduction of ATC's was grounded within these principles for a successful bit of work. This theme consisted of two subthemes: "Push where it moves" and "Training smartly". Both underscored the necessity of tailoring interventions that could be integrated into survivors' daily lives whilst also recognising long-term goals and how this supports engagement, adherence and ultimately effective ATC interventions.

### 4.5.1. Theme two, subtheme one: Push where it moves

Participants discussed the notion that ATC intervention must make sense to survivors. Indeed, rather than selecting ATCs based on neuropsychological profiles (scores from standardised tests), participants described the importance of clinical interviews and the importance of qualitative information such as the person's values, emotional well-being, and pre-injury lifestyle. To this end, the selection and adaptation of ATC's were viewed as simply an extension of neurorehabilitation services' holistic approach to care. Several clinicians reflected on the uniqueness of each case, highlighting that no single solution worked universally.

*"If we're finding something to be working, then great. I guess it's so specific to the individual as well. It's hard to generalise"* P1.

This acknowledgement of the idiosyncratic need and nature of neurorehabilitation indicated a general consensus that there was no "one-size-fits-all" approach to ATC's but that participants were comfortable embracing a process of trial, adaption, and refinement whilst keeping the survivor's personal context central to the intervention. This process often began and was sustained by turning to what survivors found personally relevant, and often this involved training the ability to function more independently with daily tasks, or to return to work.

*"I try to find something that, like, strikes a chord emotionally with the patient. Or literally even learning to say their family member's name of something like that."* P10

This is to say that participants largely recognised that it was not about improving specific cognitive functions, such as memory or language, but about supporting clients in reconnecting with people and roles that mattered to them. By focusing on the emotional significance of tasks, interventions become more than a practical exercise; they become personally meaningful, which was felt to increase the likelihood of a successful and sustained ATC intervention.

The alignment with personal relevance also extended to participants recognising the importance of understanding the clients they worked with pre-injury lifestyles and roles; *"You're depending on what the client's pre-injury lifestyle was like*" (P9). For example, patients who had previously relied heavily on mobile phones in daily life (especially if they used digital calendars etc) would be approached differently than one who had never used a smartphone at all. Participants spoke about honouring these differences to ensure that if they considered an ATC intervention, it took into account a person's "readiness" so that interventions were more likely to be embraced.

Closely tied to this was goal-setting. As P7 noted, *"[...patient centred goals, at every meeting, should be a part of the conversation.]"*. This underlines a central idea that goals are best co-constructed with the survivor instead of imposed upon them. This requires continuously checking in with clients and working closely with them, which participants endeavoured to do. As circumstances changed and goals shifted, ongoing adjustment to ATC's could then be implemented. This iterative, and goal-orientated process was also often situated within daily routines of survivors. Participants described interweaving ATC use into everyday life, almost in an unconscious level.

*"We try to tie it into usually meals. Like when you're sitting down for breakfast or you're having a cup of coffee…the first thing you do after your first sip of coffee is pull up your phone and then check your calendar for the day".* P8

By embedding ATCs into daily tasks, participants supported survivors in internalising those technologies as integral tools and extensions of their cognition, and not temporary tools to be discarded. Participants recognised that pushing too hard against resistance was often counterproductive; instead, they aimed to "roll with it", validating survivors' feelings and experiences and adjusting the approach until something that met that person's goals and personal circumstances emerged, be that an ATC intervention, or something else.

### 4.5.2. Theme two, subtheme two: Training smartly

The first subtheme captured the importance of aligning ATC interventions to the individual, "training smartly" captures the practical "methods" and timelines through which interventions were introduced by participants. Participants described training as nuanced, patient-centred at all times, considering individual capabilities, familiarity with technology, and cognitive capacities.

*"We've had recent patients that have never used a phone, and so it is worth taking into consideration this person has never organised themselves that way"* P1

In considering how best to introduce and teach intervention, participants often spoke about taking into account clients' age or cohorts and how these generational and cultural factors associated with these factors shape the learning process. Younger clients, who often had extensive pre-injury familiarity with digital technology, tended to progress more rapidly.

*"I've certainly noticed that with our younger clients it was so much quicker for us to be like, ok, let's look at your phone, let's look at the internet, let's get this stuff going"* P3.

Nevertheless, this pattern was not consistent in all cases. P8 in particular emphasised that despite this trend, there was some surprising states of technological readiness from both younger and older clients, indicating that age, or preconceived notions about technological competence did not always predict or match up to success with ATCs. This encouraged the need for a flexible approach, remaining open to the presentation of clients.

*"There's things you know from the diagnosis, the location of the injury and age stuff. But I've been repeatedly surprised in both directions"* P8

The process of training also demands significant time, patience, and resources. Participants stressed that it could take substantial time to achieve modest goals, especially if cognitive, linguistic, or motor impairments were significant. P6 described a successful ATC intervention utilising an electronic calendar that *"[…took a lot of time, a lot of time….I think if you just had 6 or 12 weeks it just never would have happened.]"*. In some cases, participants discussed how progress might begin with very fundamental steps, such as teaching someone to consistently charge their phone overnight so it would be ready to use the following day. P5 spoke about how this *"[…took a week]"* but that scaffolding was part of a wider patient-centred approach that supported the groundwork for long-term and efficacious ATC use.

A related issue was generalisation of ATC's, moving from success in a controlled clinical environment to success in the real world.

*"And that's kind of the next challenge I suppose, is that generalising it outside of this"* P1.

It highlighted that training needed to go beyond skill acquisition, but the need to consider, thoughtfully, how those skills could transfer to real-life contexts. Without this consideration, survivors might struggle to apply ATC skills that had been developed in therapy lessons, when returning to daily routines and previous roles. One way to support this was feedback and data. Participants often wanted to know how frequently clients engaged with a device or app or which features were most utilised. However, there was an acknowledgement that technologies rarely provided clinicians with direct data access. There was one exception in participants, P5, who had collaborated with Neumind (who have been mentioned previously in the thesis). She was particularly impressed with the ability to access a clinician's version of the app, in which data was readily available, and whilst she had not yet utilised it clinically, she felt optimistic about its usefulness.

*[…as clinicians' we've got a platform as well. So you know, we can send homework tasks or we could measure goals on it or we can upload videos of, you know, their different exercises they need to do."]*

Nevertheless, participants did speak about "just trying" ATC's with survivors. If a survivor tried an app or a strategy and found it helpful, this positive feedback reinforced the meaningfulness of the intervention. Conversely, if a particular approach proved unhelpful, that feedback guided clinicians and survivors toward alternative strategies. Simply encouraging survivors to "give it a go" allowed both parties to discover utility first-hand. This "just try" ethos recognised that survivors' acceptance and sustained use of ATC depended on seeing the results for themselves. In some situations, participants spoke about how patients might initially feel self-conscious and resistant to utilising devices in social settings, fearing it may appear rude. Again, encouraging them to test out tools, often in low-stake scenarios, and seeing that negative consequences did not materialise could help build confidence and alleviate anxiety. In this sense, training was not purely about cognitive or technical skill-building but also fostering psychological comfort and acceptance of ATCs, and by extension, changes following their brain injury.

*"[...sometimes we just go, yeah, it's ok if you're not sure about it. But why don't we give it a go? If it works it works, and if it doesn't we try something else?]"* P11

## 4.6. Theme three: Context matters

This theme highlights the systemic nature of working in neurorehabilitation and the process of incorporating ATC, as experienced by participants. It draws attention to the broader systemic systems that shape clinical work and influence patient outcomes. Participants emphasised that ATC implementation does not occur in isolation. Rather, it is affected by the services clinicians work in, the structure and culture of MDTs, and the involvement and readiness of family members. Three subthemes emerged: MDT working; Service matters; A family issue.

*“It’s certainly surprising, then how different approaches can be, even within the same trust it, it can be quire surprising.”* P3

### 4.6.1. Theme three, subtheme one: MDT working

Participants consistently underscored that effective ATC use depended on close, coordinated teamwork among the various professionals involved in neurorehabilitation. This perspective reflected a recognition that ATC interventions regularly operate within a therapeutic team that includes occupational therapists, speech and language therapists, neuropsychologists, physiotherapists, and case managers, among others. This brings a magnitude of trainings and skills which are invaluable for clinical work, but this mix of support requires careful coordination for ATC's to be consistently implemented.

*"So everyone will be trying to use the aid and kind of use the language of the prompts or whatever it might be"* P6

Participants described situations where a lack of alignment across the MDT could lead to inconsistency and confusion for survivors. For instance, differing rationales for using a particular memory aid or scheduling app, or even varying language and prompts for cueing the patient, could undermine the overall effectiveness of an ATC intervention. Establishing a shared understanding and approach reduced these risks and was described as essential in implementing ATCs successfully. This consistent approach allowed clinicians to "pull in the same direction," reinforcing strategies, checking progress, and adapting interventions as needed. As P1 noted:

*"A lot of the time if we can't work in a joined up way where we all know a given situation, that can be quite difficult"* P1

The importance of an MDT approach was communicated by participants consistently, and without a joint-up approach, even highly individualised and promising ATC intervention may not be fully realised because survivors may receive mixed or inconsistent support within teams. This highlighted the importance of consistent, collaborative practice that extends beyond just communication within teams. Teams that actively reinforced the same strategies and routines, and language, were better positioned to support survivors as they learned to ues ATCs. Achieving this "synergy" was helpful in allowing participants to avoid inadvertently undermining another's work

*"They're all aware of what each other are doing and not doing, things that are going to undermine another clinician."* P9

This understanding not only supported ATC's implementation but also provided dialogue for discussing and drawing on the knowledge of the MDT. In an area like ATC use, where established guidelines are sparse, and technology is ever changing, clinicians described the value of drawing upon colleagues' experiences. Through regular team meetings, case discussions, and informal exchanges, team members pooled their insights about which ATCs worked best for particular cognitive profiles, how to adapt tools to patients' language or sensory needs, and how to scaffold new skills over time. The MDT was therefore described as an invaluable resource, where clinicians could troubleshoot challenges, explore approaches, and collectively refine their practice with ATC's.

*"[...sometimes I'll just ask an OT colleague, what maybe they have used? They often have a few things that we don't use quite as much in Psychology"* P3

### 4.6.2. Theme three, subtheme two: Service matters

In addition to the importance of MDT working, participants spoke about how the broader service context in which they worked, be that public (e.g., NHS) or private, shaped their freedom, capacity, and timescales for implementing ATCs. Services were, therefore, not "neutral" settings; they influenced the range of possible interventions and the ability of clinicians to integrate ATC.

Clinicians working outside of the NHS described feeling as though they had greater freedom. Without the constraints of a large, sometimes rigid bureaucracy, they could select interventions more creatively, invest time in researching new tools, and customise solutions to individual patients' needs.

*"So we've therefore not been dictated by anything particular within the NHS that we need to offer."* P6

In contrast, some participants expressed frustration at the limited resources and bureaucratic constraints within the NHS, which could hinder flexibility and get in the way of uptake of technology within clinical practice. P2 indicated this by saying:

*"In the NHS, they won't even buy the staff a phone to be able to communicate with their patients."*

Here, a seemingly minor equipment issue symbolised broader systemic limitations. If basic tools such as smartphones were challenging to obtain, the culture to experiment and try new technologies was also somewhat absent. The result; an impact to the ability for clinicians to engage in ATC intervention to their full potential. However, this was not consistently the case for all NHS participants. Some did not feel there was this systematic resistance or explicit limitation in working for the NHS. As P1 shared *[“We’re all quite on board with technology…”]* from her NHS role. Nevertheless, organisational cultures, funding models, and commissioning arrangements influenced the degree of technological adoption, the length of interventions, and the kinds of support that were feasible over time.

Timeframes and funding streams were also crucial. While some services could commit to long-term interventions, others operated within short-term models, making it harder to achieve meaningful, sustainable changes with ATC. Short-term engagements might allow for basic goal-setting and introduction of an ATC, but insufficient time would be available for iterative refinement, troubleshooting, or reinforcing habits to the point of full integration. Without continuity, survivors might abandon or underuse ATCs once interventions ended.

*"So many services are so limited by such short interventions"* P6

This complexity highlights that "service matters" deeply. The structural and cultural features of a service, the policies, resources, and culture, could empower clinicians to explore, adapt, and integrate ATCs comprehensively or constrain them to partial, fragmented efforts.

### 4.6.3. Theme three, subtheme three: A family issue

While the influence of services and MDTs framed a significant part of participants' work, they also highlighted the important role that families played in neurorehabilitation and how this applied to implementing ATCs. Family involvement could extend the impact of ATC-related strategies beyond the clinical setting, embedding them into survivors' everyday routines. Families could provide practical support, such as reminders to use a memory aid or assistance in setting up a device, and emotional encouragement, reinforcing the notion that ATC use could be a legitimate and beneficial part of daily life.

However, participants recognised that working with families was not always straightforward. Families, like services, came with their own constraints and complexities. They might struggle with time, other life commitments or caregiving responsibilities, or indeed the emotional adjustment following a loved one's brain injury. As P4 noted:

*"I certainly think time can be hard. Juggling all those other commitments that they have, life doesn't stop."*

It was highlighted that families are often doing their best within challenging circumstances. They might wish to support ATC use but lack the resources, time, or energy to do so consistently. Some families were geographically distant, financially limited, or emotionally exhausted by caregiver burden. The ideal scenario, where families eagerly embraced ATC interventions and supported there use outside of therapy sessions, was not always feasible. Participants shared that sometimes families were simply unable to provide this type of support. There was a sense that participants recognised a need to be pragmatic and acknowledge that not all families could play an active role in supporting ATC integration and therefore was not a resource that could be assumed.

Nevertheless, some families were able to provide support. However, in these circumstances, there were important dynamics at play. Balancing the family's desire to help with the patient's goals (often independence) could also be challenging. While families might be eager to assist, over-involvement could inadvertently limit the survivors autonomy or sense of ownership over their rehabilitation. Reflecting on this complexity, P2 shared a situation where families might overcompensate, accidentally limiting the patient's autonomy. In these situations, it was described as important to navigate these dynamics sensitively, often by providing psychoeducation to families about the role of the intervention and encouraging a balance between support and allowing survivors to practice skills independently.

*"You know, so many like I said, so many family members or close others, they do mean really well, but…then stepping in before the patient has a chance to recognise the need for the compensatory aid in the first place." P2*

Despite these dynamics, participants shared that they generally tried to include families wherever possible, considering them to be potentially very beneficial in supporting their clients. When it worked well, family involvement could bridge or mitigate gaps in care, sustaining survivors' progress with ATCs over time and creating continuity between the clinical and home environments. A well-informed and motivated family could help the survivor practice new strategies repeatedly, troubleshoot minor issues, and celebrate incremental achievements. Such involvement potentially enhanced the long-term retention and generalisation of ATC-acquired skills.

*"They can be super helpful!"* P12 (on family involvement)

## 4.7. Theme 4: Professionals bring themselves

This theme captured that ATC implementation is not solely a matter of technical design, service structures, or patient characteristics (although important). It is also intertwined with the clinicians' own identities, comfort with technology, and capacity to develop meaningful therapeutic relationship with the service users they work with. Participants spoke about how these aspects of themselves and others influenced the application of ATC interventions. Two subthemes were developed: "Comfort with technology" and "The therapeutic relationship". These subthemes captured that effective ATC implantation isn't just a technical exercise, but one that can depend on what each clinician brings uniquely.

*"That's been my experience. I really enjoy it. I find technology really interesting and practical."* P1

### 4.7.1. Theme four, subtheme one: Comfort with technology

Clinicians' personal comfort with technology surfaced as a significant factor influencing ATC use with clinical practice. Comfort here refers not only to technical competence but also the willingness to explore new tools and adapt interventions, which installs confidence in the survivors they work with. Participants made it clear that clinicians who lacked familiarity or ease with technology were absent from ATC-led interventions. This struggle was hypothesised by participants, who had seen it manifest in other professionals and was viewed in light of a degree of uncertainty in selecting from a rapidly evolving landscape of apps and devices (and was also shared by those more comfortable). In contrast, participants, who largely felt at ease with technology described actively researching new options. However, even within the participant pool, who were significantly skewed towards being open to technology, there were those who clearly were more passionate and interested in the area. P10 described actively being part of bodies with SALT in the USA which were not necessary for her practice, but because she was interested in the area, and subsequently attended conferences around the use of technology in healthcare.

*"[…It's just very self-motivated, and we have special interest groups without our association…but its really hard because you're working full time…it's all self-motivated*" P10

To this end, participants also noted how their own training influenced fluency and comfort with technology in clinical practice. Participants P2 and P5 noted that SALT's seemed particularly adept and more accustomed to working with technology-based interventions. P10, the only SLT interviewed, did confirm technology was threaded into her training, but even in this discipline, that appeared particularly up to date with ATC's, was not totally sufficient. She shared "So you do your graduate training, you graduate, you're expected to be an expert, but you can't be". This highlighted that certain professional training might be more accustomed to preparing clinicians to incorporate digital tools, but there was no indication any of them are fully sufficient. Given that the participant pool was heavily skewed towards clinical psychology, it was interesting that the psychologists interviewed did not raise their training as having prepared them to utilise technology. In conjunction with this, some participants expressed that training programs or university curricula had not kept pace with the technological changes in rehabilitation, leaving many to learn on the job. Bridging this gap required initiative on the clinician's part:

*"If I don't know how to use it as a clinician, how can I be expected to, like, train my patient to use it"*- P9.

These reflections also pointed to the individual attributes participants brought to their work, and the interview,; largely a curiosity, motivation, personal interest, and a willingness to "just try", which are crucial in working in this area. Because of this, participants alluded to being resources for their teams to draw upon. However, there was a noted divide between qualified staff and non-qualified. Those who occupied more senior or leadership roles described feeling empowered to seek out and research, and then implement, emerging technologies, or adapting existing ones. They had the authority and confidence to integrate these tools, which perhaps came from the power they held within the teams they worked in. Conversely, non-qualified staff (assistant psychologists) did not report the same experiences but did describe working within established boundaries set by supervisors. This alluded to a power differential that does occur within the workplace, clinically, and how because of it some clinicians are better placed to be more creative with ATC interventions.

*"So there's all these things online where they have these games just to practise your ability and accuracy using your mouse for shooing games. But I think, yeah, we just kind of drift into different industries and you know, I always think this, the gaming industry is so vast."* P3

Age and length of professional experience also intersected with comfort with technology, although not always in predictable ways. Some more experienced clinicians, such as P7 & P8, noted that they had witnessed a significant evolution in ATCs over their careers. This long-term perspective could manifest as enthusiasm for innovation, seeing new tools as opportunities to improve patient outcomes, or could create apprehension as technological complexity surpassed what their training had covered. P3 described how rapid technological changes sometimes created a sense of dislocation or helplessness in other clinicians:

*"If that individual themselves, however, struggles with technology, then of course it's going to be more challenging for them and probably a little bit more reluctant."* (P3)

Participants expressed that if a clinician felt uncomfortable with ATC's that this might "transfer" onto the clients they work with; and therefore influenced the relational dynamics of ATC being introduced and pursued as a rehabilitation intervention. In comparison it could be suggested that clinicians who did feel comfortable, also inspired confidence.

### 4.7.2. Theme four, subtheme two: The therapeutic relationship

In line with what participants brought about themselves, they also spoke about the modality by which it was used: the therapeutic relationship. This provided the interpersonal component in which ATC's were introduced and used. To this end, participant's consistently emphasised that rehabilitation is not merely a technical process, of matching an ATC to a client based on cognitive deficits. Rather, it is relational, in which clinicians' values are touched upon, and trust, empathy, and collaboration can be nurtured. The therapeutic relationship underpinned meaningful ATC use by ensuring that interventions aligned with survivors' goals, emotional states, and evolving needs. But this went beyond the previous themes in describing a relational depth, and need, in which to work with survivors.

*[...you get to know them, and what work with them, specifically.]"* P9

There was also a sense that these relationships were reciprocal, or at least, not hierarchically fixed. P8 shared "*Sometimes the clients educate us you know…and we're all about them becoming proficient"*. Survivors and families contributed to participant's expertise and reciprocally shaped ATC interventions. Rather than assuming the stance of an all-knowing expert, participants described embracing a collaborative dynamic that recognised survivors' lived experiences that could guide the intervention but also support them to become more proficient clinicians.

Participants also spoke about how guided discovery and joint reflection were hallmarks of a strong therapeutic alliance. Participants would weigh up pros and cons of different ATC's, connecting an intervention with what mattered most in the survivors' life, be it returning to work, managing everyday tasks more independently, or maintaining social connections. Participants described supporting participants to make decisions, suggesting that ATC interventions where more resonant if survivors felt a sense of agency and personal involvement:

*"[…you kind of have to guide them to thinking of it on their own, you know.]"* P11

A strong therapeutic relationship also offered a buffering against the frustration and setbacks that commonly arose when using ATCs. Rehabilitation is often an iterative process, marked by trial-and-error, and shifting client needs. Participants expressed empathy for survivors who faced these challenges, and in turn recognised that they themselves sometimes felt a sense of frustration and powerless at lack of resources, technology, or simply clinical realities. P6 described wishing they could code their own app because they knew precisely what their patient needed but had no way to create it:

*"[….often I'm like, oh god, why can't I make apps? Why can't I code?]"*- P6

Another dimension of the therapeutic relationship revolved around empathy, trust-building, and emotional state. Participants described how understanding survivors' values, fears, and aspirations was critical to sustaining engagement with ATCs. If a particular tool did not resonate with what the survivor deemed important, or if it failed to offer a tangible improvement in day-to-day activities, motivation would wane. Participants spoke about noticing these signals, adjusting their approach, suggesting alternative technologies, or introducing incremental steps to make an intervention manageable. P2 highlighted that knowing the patient "really well" and taking time to build rapport allowed for these idiosyncratic adjustments:

*"You know, let's try something else, but I think that takes knowing your patient really well and that takes time."* (P2)

The therapeutic relationship also created space for emotional work. Survivors navigating cognitive challenges post-injury often faced grief, anxiety, and uncertainty. ATCs might ease these burdens, but they could also highlight limitations or remind survivors of changed capacities. Clinicians who recognised and validated these emotional difficulties contributed to a sense of safety and trust. When survivors felt understood and respected, even unsuccessful attempts with certain tools could be reframed as learning experiences rather than failures. In this relational context, persistence, adaptation, and problem-solving flourished.

*"I do think it's important to build that trust…especially with working with adults, it's kind of more relational."* P11

Participants also brought their own personal experiences, and how it intersected and informed there work in this area. P5 shared *"I've also gone through it as a caregiver, because my grandma had dementia"*. By drawing upon personal experience participants’ emphasis more deeply with the clients they worked with, supporting the development of a therapeutic alliance beyond the hierarchical position of "patient" and "professional".

These two subthemes frame that ATC integration should be viewed as a part of a relational process, and not just a technological one. It is contingent on the involvement of others, normally clinicians, in which clinicians own capacities, constraints, and relationships interplay into clinical interventions. To this end, clinicians do not just deliver interventions; they actively shape them through their personal ease with technology, their openness to learn from patients (and families), and their ability to foster trust and empathy. This interplay suggests that training and guidelines alone are insufficient; meaningful ATC implementation also depends on a relational element between clients and clinicians.

## 4.8. Theme 5: Beyond the injury

This theme shifts away from the participants own experience and onto their perceived experiences of survivors of brain injury. Whilst previous themes have highlighted service structure, MDT working, family involvement, clinicians' personal selves, and the therapeutic relationship, this theme takes a more survivor-centred perspective, capturing the profound and ongoing process of adjustment and identify recognition that occurs following the injury. It underscores that people living with brain injury are not defined solely by their cognitive deficits or functional limitations. Instead, they are individuals navigating complex emotional, social and psychological processes.

Survivors of brain injury often face a significant and multifaceted adjustment process. Participants described this as a dynamic process of re-negotiation of identity. This adjustment is non-linear. Rather, it unfolds over time. Participants described the the clients they worked with as grappling with losses; loss of familiar roles, careers, hobbies, and social positions, as well as changes in cognition, or physical mobility. The introduction of ATCs into their rehabilitation journey occurs against this backdrop of flux, vulnerability, and, importantly, hope.

*"I think some people, they just want to be able to get back to how they were doing before*" P3

This longing for a pre-injury state underscores the centrality of identity in the rehabilitation context. Participants perceived that the survivors of TBI they worked with often measure progress not simply by clinical indicators but by the degree to which they feel closer to their "old selves." ATCs may help re-establish routines, rebuild competencies, or support independence in activities of daily living. Yet, technology cannot fully restore what was lost. Instead, survivors and clinicians together navigate the tension between reclaiming old aspects of identity and forging a new sense of self. P 11 pointed out that survivors may express resentment, questioning why they have to perform tasks that were once trivial:

*"They're used to things being relatively easy….it's like "I didn't have to do all this crap before""*

That frustration is symptomatic of the identity shift survivors are negotiating, which participants stated they and their clients were aware of. Tasks that were once effortless, such as managing finances, attending appointments, and remembering names, now required support. The act of relying on a ATC's could, therefore, be helpful, but also a reminder of that loss, challenging the survivor's sense of autonomy. Indeed, P2 also noted this and that a client they had worked with who was unable to manage their own banking independently became a source of shame for them.

*“[…I had a patient…his family still hadn’t given him a bank card….and so we were like, let’s get the banking app up, let’s get trained in the banking app. But he found it really infantilizing.”]* P2

Some participants recognised that brain injuries are often "invisible," intensifying the disconnect between survivors' external appearances and their internal struggles. P1 observed that physical impairments are more visibly understood by the public than cognitive ones describing the importance of "*reminding people of the invisible injury*.”. Participants described this as contributing to a sense of perceived isolation in clients, who may feel misunderstood or unsupported. This further provided depth to the application of ATC's clinically; that they must be contextualised, taking note of survivors’ complex emotional experiences, and embedded in a broader therapeutic process that recognises the complexity, grief, and work of rebuilding survivors are going through.

Closely entwined with identity and adjustment is the concept of motivation. Engaging with ATCs, practicing new skills, and persisting through setbacks require sustained effort. Participants emphasised that motivation is not static. Rather, it fluctuates and must be nurtured within a a relational framework that acknowledges how challenging their journey can be.

*"It's a lot of work for them"* P12.

This concise statement encapsulated a key point about neurorehabiliation. Survivors, and there families, must invest considerable energy, cognitive, emotional, financial, into acquiring, learning, and regularly using ATC's.

*"Whether or not it's because of the cognitive difficulty or because they've got so much stress going on anyway, they just don't want to deal with another frustration."* P4

Motivation cannot be separated from the survivors broader life contexts, as it can depend on all of these factors, as well as the complex consequences following a brain injury. Additionally, cultural differences were alluded to by participants, but most explicitly by P10 who stated:

*"Culture plays such a huge role… it affects everything from how they perceive you to how they communicate with you, to how they accept your recommendations."*

Motivation is not simply about convincing survivors to "try harder." Instead, it involves understanding their lived experiences and creating a supportive environment that resonates with their values. Participants recognised that ATC use can support meaningful exchanges and quality of life, which can, in turn, bolster motivation if a survivor perceives an ATC as enhancing their quality of life. In essence, this theme captured that the cognitive deficits being supported must also be supported alongside the person and that whilst ATC can be helpful in supporting life after TBI, they must be introduced with careful consideration and recognition that a personhood extends far beyond a cognitive deficit. Participants largely recognised that these tools can become stepping stone in a meaningful reconstruction of life after injury.

## 4.9. Reflexivity

I initially approached the analysis that a primarily semantic approach, as outlined in the methodology chapter, would be the most useful means of addressing my research questions. This would allow me to capture themes as directly as possible from participants' perspectives. This was largely achievable, as participants shared contrasting and overlapping experiences, particularly regarding what had been effective for them and their clients. However, I was struck by the extent to which a latent analysis naturally unfolded alongside the semantic analysis, as this became necessary for fully developing the themes. While I anticipated some degree of latent analysis would be inevitable, I was surprised by how integral it became in making sense of the data.

A particularly notable pattern emerged in the interviews: many participants initially felt they had little to say on the topic. However, through discussion, it became evident that they had much to contribute, with the depth of their experiences only becoming fully apparent in the analysis. On numerous occasions, rather than speaking directly about technology, participants instead focused on their clients, describing their characteristics and lived experiences in broader terms. Although this was not immediately linked to the topic of ATC's, its recurrence suggested it held relevance. Furthermore, participants frequently spoke about their own professional identities, their roles within teams, and their experiences within their professions. These discussions, while not strictly about ATC, felt crucial to understanding the broader context in which these interventions were implemented. Consequently, a more latent approach became necessary to fully develop the themes that emerged from the data.

I also reflected on what these topics brought up in myself, and my own experiences as a clinician and working within MDTs in various roles. While I remained mindful of this throughout the analysis, I recognise that my familiarity with these professional dynamics likely supported me in making sense of the data. Given that this was an RAT, what I brought to the data, and those of participants, will have shaped my interpretations in meaningful ways, reinforcing the iterative and interpretative nature of the analytic process.

# 5. Chapter five- Discussion

### 5.1.1. Summary of Findings

This thesis presents a reflexive thematic analysis of clinicians' experiences working in neurorehabilitation and their experiences implementing ATCs. The study aimed to explore clinicians' experiences to understand the factors that contribute to successful implementation and management or, conversely, what gets in the way. This is particularly relevant given the paradox of ATCs being widely available yet not reaching their potential, as highlighted by multiple systematic reviews.

The findings of this research align with existing literature, reinforcing observations about the growing potential of ATCs in neurorehabilitation and the systemic and practical challenges faced by clients, clinicians, and services. However, this study adds a new dimension by emphasising the transient and relational dynamics that shape ATC implementation. While such factors are well understood within professions like clinical psychology, they have not yet been explicitly incorporated into discussions on assistive technology use in neurorehabilitation.

### 5.1.2. Smartphones: Useful but Limited

A key finding of this study is that smartphones are the most commonly used ATCs across neurorehabilitation services. Clinicians from different disciplines acknowledged their practicality and accessibility, which aligns with earlier predictions and the increasing ubiquity of smartphones discussed in the introduction (Gillespie et al., 2012). Their affordability and adaptability were seen as advantages, particularly compared to specialist assistive devices, which tend to be costly and normally unfamiliar to clients. Additionally, the widespread ownership of smartphones reduces the stigma associated with ATCs, making them more acceptable, a pattern echoed in previous research with older adults with ABI (Wilson et al., 2022). These findings further support recommendations that individuals with TBI should use their own devices for cognitive support rather than being introduced to new, unfamiliar technologies (Charters et al., 2015).

Despite their advantages, smartphones remain underutilised as ATCs. Clinicians highlighted that, of all the functions available, electronic calendar systems were used the most, findings that mirror those of the literature reviewed in Chapter 2. However, many other features remain largely untapped. While electronic calendars and reminder apps are flexible and widely used, the study also revealed that many ATC apps are not intuitive enough for individuals with cognitive difficulties, reducing their usefulness.

Another challenge the analysis identified was the overwhelming number of available applications, which creates a paradox of choice and can be counterproductive. While there are thousands of apps designed to support cognitive function, the lack of standardised recommendations and empirical validation limits their practical application. These findings are consistent with those of Ownsworth et al. (2023), who similarly noted the absence of clear guidelines for selecting ATCs. Without structured evaluation frameworks, clinicians are often left to rely on trial and error when determining which applications to recommend, leading to inconsistencies across services.

### 5.1.3. Adapting Smartphones and Other Technologies

Although smartphones and other mainstream technologies are widely used in neurorehabilitation, they are not specifically designed for individuals with brain injuries. As a result, clinicians must often modify them to improve usability. The study highlighted that selecting an appropriate ATC and determining how best to use it requires balancing an individual's premorbid technological competence, cognitive profile, and the existence of a physical disability. Simple modifications, such as increasing font size or adjusting colour schemes, can enhance usability and support the prevention of overwhelming users.

Interestingly, the clinicians in this study primarily relied on existing smartphone functions or repurposed non-specialist technologies rather than purpose-built ATCs. This aligns with recent research showing that TBI survivors also predominantly use built-in smartphone features rather than bespoke assistive tools (Beaulieu-Bonneau et al., 2024). Much of the existing research has focused on developing new assistive technologies rather than examining how mainstream devices, such as smartphones or even video game systems, can be adapted for rehabilitation. Some clinicians suggested that existing technologies could be applied creatively, though this often requires trial and error to match interventions to an individual's needs and preferences. While there is emerging evidence for novel ATC interventions, caution is warranted; systematic reviews have found mixed results regarding the effectiveness of virtual reality (VR) based rehabilitation and gaming systems such as the Nintendo Wii or Xbox Kinect in cognitive rehabilitation (Bonanno et al., 2022). This suggests that adapting technologies other than smartphones has potential, it needs to be done cautiously whilst there is limited evidence of its efficacy.

### 5.1.4. Family Involvement in ATC Interventions

The role of family members in supporting ATC use emerged as a key theme in the analysis. It is widely accepted that brain injuries impact not just the individual but their broader support network. As such, professionals are increasingly encouraged to adopt a systems-based approach to rehabilitation, integrating family routines to promote consistency in ATC use (ICF, 2001). Participants in this study echoed previous findings that caregiver involvement can enhance rehabilitation outcomes (Bivona et al., 2020).

However, the manner in which families are involved requires careful consideration. While structured family interventions have been shown to improve functional outcomes, other studies have found no significant benefit when family therapy is added to already intensive rehabilitation programmes (Rasmussen et al., 2021). This suggests individualised approaches are needed, and while family support can be valuable, it is not always available, and excessive involvement may inadvertently undermine an intervention. The analysis also highlighted the importance of psychoeducation for families, helping them understand how best to support ATC use without inadvertently diminishing the user's independence. This aligns with broader research on acquired brain injury, which has shown that psychoeducation can improve family communication, cohesion, and problem-solving (Zhou et al., 2021).

### 5.1.5. The need for long term support and training

Smartphones may be a pragmatic choice for ATC interventions, but their effectiveness is intertwined with training and sustained support for clients. The findings suggest that even clients who were previously comfortable with technology often struggle to use ATCs in a compensatory way following brain injury. This may be due to the direct effects of their injury but also the emotional and behavioural adjustments required to integrate new habits. Previous studies have found that 31% of ABI survivors report increased difficulty using their phones post-injury, with 36% requiring retraining to use them effectively (Beaulieu-Bonneau et al., 2024). This highlights the importance of considering training when designing ATC interventions.

The findings also suggest that ATC interventions should be positioned as long-term strategies rather than short-term rehabilitation tools. While many neurorehabilitation services, such as NHS stroke rehabilitation programmes, operate within fixed-term frameworks (typically six to eight weeks), participants in this study indicated that ATCs require ongoing support spanning months or even years. This contrasts with much of the existing literature, which tends to provide vague descriptions of the extent and intensity of ATC training required. The results suggest that ongoing training and reinforcement may be crucial to the long-term success of ATC interventions.

## 5.2. Implications for Clinical Practice

The findings of this study have several implications for clinicians delivering ATC interventions in neurorehabilitation settings. Firstly, smartphones appear to be a practical and accessible platform for compensatory interventions. However, understanding each client's goals and adaptations should form a central part of the initial assessment and should be reviewed regularly. Clinicians should be open to adjusting or replacing ATCs on a case-by-case basis, ensuring a collaborative approach that is in line with recommendations for person centred care, such as those described by the British Psychological Society (BPS, 2018).

Financial barriers remain a significant challenge despite the widespread availability of smartphones. Many tailor-made apps designed to support cognition require payment, limiting accessibility. Clinicians should advocate for systemic funding changes to ensure equitable access and, in the interim, prioritise free or built-in smartphone functionalities. Additionally, training and general familiarity with ATCs are necessary for clinicians to gain confidence in their use and, by extension, for successful interventions.

## 5.3. Strengths and Limitations of the Present Study

A significant limitation of this study is that it does not directly investigate the perspectives of individuals with brain injuries. Clinicians provided valuable insights into the implementation of ATC's, but it remains unclear how cognitive impairments directly affect engagement with these tools. For example, we still don't fully understand how self-awareness affects whether someone engages with ATC. It's possible that people who recognise their cognitive difficulties are more motivated to use these tools, whereas those with reduced insight might not see the need or may struggle to engage. Future research should explore this further, particularly by incorporating the perspectives of individuals living with brain injury.

There are also questions about how different demographic factors shape ATC use. For instance, Wong et al. (2021) found that older adults were less likely to use mobile devices for cognitive support after a stroke. While their study highlighted some age-related differences, it didn't go far enough in unpacking the reasons behind them. It remains unclear whether older adults need different types of support, more training, or alternative approaches to make ATC work for them. Further research is needed to explore how digital literacy, generational differences, and rehabilitation needs intersect to shape ATC adoption.

Another limitation is the demographics of the sample. The majority of participants came from a WEIRD (Western, Educated, Industrialised, Rich, and Democratic) background, limiting the generalisability of the findings. This is a result of convenience sampling. Furthermore, clinicians who are less engaged with technology or who hold more sceptical views about ATCs may have been less likely to participate, meaning their perspectives, which could have provided valuable insights, were not captured.

Almost all participants in this study identified as white, with only one exception. It is well established that people from ethnic minority backgrounds are often underrepresented in research, and this study did not do enough to address that imbalance in its recruitment strategy (Wendler et al., 2006). Given that ethnic minority groups can face additional barriers to accessing healthcare, the lack of diverse representation here makes it harder to generalise these findings more widely. Future research should take a more inclusive approach to recruitment, ensuring that the experiences of a broader range of clinicians working in neurorehabilitation are reflected.

That said, a key strength of this study is its focus on clinicians, who play a central role in supporting ATC use in neurorehabilitation. By gathering insights from a range of healthcare professionals, this research provides a multidisciplinary perspective on ATC implementation. Since multidisciplinary teams (MDTs) are vital in neurorehabilitation—and in making ATC interventions work—these findings offer valuable insights that could help shape future training and intervention strategies.

## 5.4. Suggestions for future research

This study highlights several areas for future research.

First, there is a need for further investigation into the usability of ATCs. The Unified Theory of Acceptance and Use of Technology (UTAUT) provides a well-established framework for understanding how individuals adopt and sustain technology use. The model identifies four key constructs that influence technology use: performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003). Using this framework future research could explore how factors such as perceived ease of use, usefulness, and attitudes of both clinicians and survivors influence the integration of ATCs into daily routines. Since clinicians play a key role in recommending and supporting ATC use, professional attitudes towards technology should also be examined.

Second, while previous research has often taken a deficit-based perspective, focusing on how cognitive impairments affect technology uptake, a profession-based approach may offer fresh insights. Investigating how different disciplines within neurorehabilitation conceptualise and integrate ATCs could shed light on variations in practice and help inform support for clients and clinicians. The analysis of this study how professional identity, training, and systemic structures shape ATC interventions, and further exploration of clinician experience would be useful.

Additionally, a significant gap remains in research exploring the perspectives of brain injury survivors and their families regarding ATC use. Future qualitative studies could provide a richer understanding of user experiences, identifying barriers to adoption, factors that encourage long-term engagement, and areas for improvement. Family involvement was highlighted in this research as a factor in ATC use, suggesting that further research should examine the impact of psychoeducation for families on ATC effectiveness and long-term use.

One of the biggest challenges in this field is the lack of clear guidance on how ATCs should be implemented in neurorehabilitation services. Without evidence-based guidelines, clinicians are left to figure things out on their own, leading to inconsistencies in how these tools are used across different services. Research that develops and tests structured guidelines would be invaluable in making sure ATCs are integrated effectively and consistently in clinical practice.

Future research needs to take a broader approach when measuring outcomes. While qualitative studies offer rich insights into user experiences, we also need robust quantitative research to systematically assess how ATCs impact health-related quality of life (HRQoL) for both survivors and their families. Longitudinal studies that track outcomes and use over time, in the short, medium, or long term, would help identify the most effective levels of intervention, support, and training, and when. This kind of research could ultimately shape best practices and ensure that ATCs are implemented in a way that is both sustainable and meaningful for those who rely on them.

## 5.5. Implications for clinical psychology

Clinical Psychologists are uniquely positioned to support the implementation of ATCs in neurorehabilitation. Their training, which follows a "scientist-practitioner model", equips them with clinical experience and research training. However, despite the emphasis on research within training, in which trainee clinical psychologists must complete a doctoral thesis, there is a long-standing recognition that many clinical psychologists do not engage in research by publishing in peer-reviewed journals or conducting empirical studies. (Smith &Thew, 2017). Nevertheless, while this is often attributed to time constraints and demands of service pressures, it may be helpful to broaden what it means to be active in research. This could include reading literature, reviewing guidelines, and staying up to date with recent field advances (Smith & Thew, 2017). Attending conferences, reading and reviewing emerging research on ATC's, and shaping service guidelines are all avenues through which clinical psychologists can influence the effective and equitable adoption of ATC's in neurorehabilitation.

## 5.6. Implications for technology developers

In light of this thesis technology developers are strongly encouraged to collaborate directly with clinicians working in neurorehabiliation contexts. Developers should not only consider the needs of those with cognitive difficulties but of the clinicians who support and monitor their use. In particular, clinicians expressed a need to access client user data in formats that are accessible and meaningful. Such an example would be a parallel interface or clinician dashboard that enables them to view usage, identify any emerging needs, and potentially communicate with users. Accessibility, across cognitive and financial domains, should also be prioritised to ensure equitable use. There is the dilemma of financial funding, which is an ongoing challenge in an underfunded area. Whilst modern technologies have largely moved towards subscription models, it must be considered whether than is the correct model for a group a people who may not be as financially secure as the general population. Indeed, subsidising such models with advert models may not be conducive to long term engagement. Therefore developers should also aim to work closely with social and health authorities to identify funding opportunities that support equitable, long-term access and implementation.

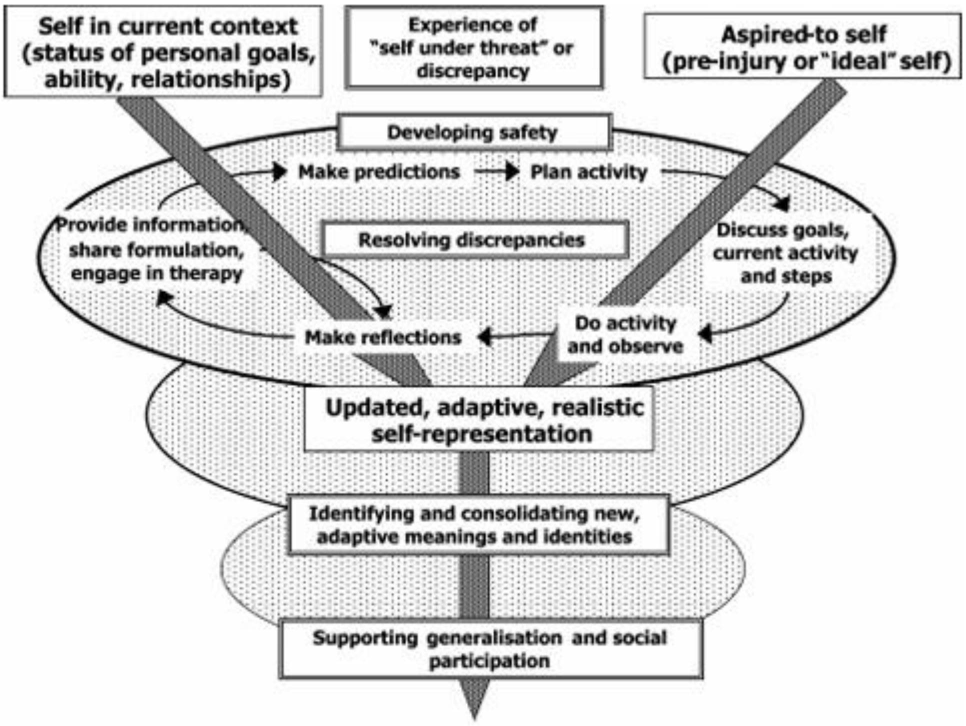
### 5.6.1. Formulation

The findings of this research suggest that person-centred integration of interventions is key to engagement and efficacy. A key challenge is, therefore, ensuring that technology is not superficially added onto clients' rehabilitation but is meaningfully embedded idiosyncratically. Psychological formulation, a core competency of clinical psychologists, is a framework from which this can be achieved. One such formulation model, biopsychosocial, was described in the introduction chapter. Indeed, these types of models have been recommended by neurorehabilitation programmes such as at the world-renowned Oliver Zangwill Centre (Wilson, 2008). However, whilst holistic, these models may not be as helpful in applying to ATC's, although will likely still be a good place to begin intervention.

This is because they focus more on deficit and are complex, making them more challenging for clients and other staff members to understand. This is important, given that formulation should be conducted and co-created with the client and/or family, as it promotes a shared understanding, facilitating motivation and engagement (Wilson & Betteridge, 2019). Another model that aligns closely with the demands of ATC implementations is the Y-shape model of adjustment (see Figure 4). This model was developed to capture the process of adjustment from ABI and captures the process of managing the pre-injury sense of self, current functioning, and the process of reconstructing a new sense of self.  It posits “discrepancies’” in sense of self that can be worked through a cycle of “experiments”. ATCs also mirror this process as successful long-term integration requires them to construct new routines and strategies within already existing ones. This model provides a structured way for clinicians to frame this process, helping clients and teams expect and understand the dynamic model of adaptation, which rarely has a linear pathway. The Y-shape model offers a tangible and clinically applicable way to scaffold ATC interventions and guide clients and teams on what to expect in regard to resistance, difficulties, and realistic goals.

**Figure 4**

*Y-shape model of adjustment (Gracey et al., 2009)*



### 5.6.2. Team formulation

Formulation is also powerful when held at the team level. Findings from this study highlight that consistent, organised MDT approaches are crucial in supporting ATCs. One way clinical psychologists can facilitate this is through team formulation. Team formulations are structured discussions that bring professionals together to develop a shared understanding of patients' needs, strengths, and challenges (Johnstone & Dallos, 2013). Given the complexity of neurorehabilitation, where interventions often span multiple services and professionals, team formulation provides a way to support coherent care across teams. Crucially, this process also provides an opportunity to engage managers and service leads, making the case for investment in ATC's.

Additionally, patients and families can be involved in team formulation approaches. While team formulation has traditionally focused on professional discussions, there is increasing interest in involving patients and their support networks, particularly where engagement barriers exist (Langford et al., 2021). This is particularly relevant for ATC adoption, where attrition and non-use remain key challenges. By involving patients and families in the formulation process, clinicians can co-develop ATC strategies that match the individual's everyday routines, increasing the chances of efficacy. In essence, formulation-driven approaches operationalise in clinical practice the final theme of the analysis:*The Person Beyond the Injury*. This ensures that personal preferences, values, and client roles inform ATC implementation rather than technology being imposed in a prescriptive manner.

## 5.7. Reflexivity

As had been discussed, I did not arrive at this topic of research by accident; I am interested in how technology can be used within healthcare, and I have professional experience working with neurological conditions. These factors will have influenced the findings. As outlined in previous chapters, the themes that "emerge" from the data are co-created. My own subjectivity inevitably influences the research, the development of the interview questions, my interactions with participants, and, subsequently, the analysis and its interpretation. I recognise that I value the role of person-centred care and the importance of acknowledging intersectionality, which has motivated me to engage in a professional doctorate in clinical psychology.

Nevertheless, I do not believe that these factors have overly influenced the findings. I had not anticipated the extent to which the therapeutic relationship would have been experienced as being central to successful ATC interventions, and inversely, I had thought the input of family members and carers might have had a more overwhelmingly positive and important role in interventions. Equally, whilst I was aware of financial barriers, from my own clinical experience and the literature, I had not anticipated that participants would give them such importance.

It is almost certain that another researcher conducting this research and analysing the data would have co-created different themes and contextualised them differently. Therefore, the themes identified in this research are placed as plausible rather than definitive, in line with RTA methodology. Alternative and equally valid interpretations could be made from the data, but nevertheless, this research does contribute important and relevant findings.

This research has contributed to the area of ATC but has also been a significant part of my training as a clinical psychologist. The process of conducting this study and designing research incorporating technology in healthcare has been a formative learning experience. To this end, engaging in this research required more than just interest. This study evolved significantly from its original conception due to ethical, feasibility, and practical considerations requiring a shift from an intended single-case experimental design study, which would have involved direct testing of an ATC. That ATC changed significantly from the inception of my original research idea, highlighting the dynamic nature of research into technology. These challenges have been opportunities to understand the type and kind of research clinical psychology does, both clinically relevant but also grounded in pragmatism, and how overcoming these challenges can still result in valuable and relevant research. This thesis, therefore, is a critical part of my development as a clinical psychologist, developing my skills to integrate research and practice in a meaningful and impactful way.

## 5.8. Conclusion

This thesis has explored the role of ATC in neurorehabilitation, focusing on how it is used in clinical practice and the factors that influence its success. Through a systematic review and a qualitative study with clinicians, this research has contributed to the growing research on how ATC can support people living with traumatic brain injury. While there is clear enthusiasm for the potential of ATC, this study highlights that its effectiveness is not simply about whether the technology works; it is about how it is introduced, supported, and embedded within rehabilitation in a way that makes sense for both survivors and the teams around them. The RTA analysis in this study described a landscape where ATC is at risk of being inconsistently integrated into care, with its success depending as much on professional confidence and service structures as on the capabilities of the technology itself. At its best, ATC was seen as a valuable tool for promoting independence, but when poorly implemented, it could be overwhelming, frustrating, or resulting in abandonment. A key theme that emerged was the importance of context, how well ATC fits into an individual's daily life, how much support they have to use it, and whether services take the time to embed it meaningfully into rehabilitation. This reinforces the idea that technology alone is not a solution; how it is framed, introduced, and supported determines its success.

This thesis also highlights the unique role of clinical psychologists in ATC implementation. As professionals trained in both research and clinical work, psychologists are well positioned to support its integration in ways that go beyond simply 'prescribing' a device or app. Person-centred care was identified as particularly relevant in this context. From this, formulation has been considered as a pragmatic approach to provide a way to understand a person's cognitive, emotional, and social needs in a structured and meaningful way. The Y-shape model of adjustment was discussed as being an especially useful framework for supporting ATC adoption, as it can be applied to the reality of using these tools, which goes beyond compensating with cognitive deficits but about adjusting, redefining roles, and rebuilding confidence in daily life for survivors.

Findings from this study suggest that well-organised, consistent multidisciplinary working is essential for ensuring that ATC interventions are not just available but actually useful. Creating space for structured discussions, shared decision-making, and professional reflection, both within teams and with survivors themselves, may be one of the most effective ways to ensure ATC is integrated in a way that lasts.

This study provides useful insights but also provides direction for future research. Future research should prioritise understanding ATC adoption from the perspectives of both survivors and clinicians, particularly those who struggle to engage with these tools. Beyond this, moving away from a deficit-based lens towards a profession-based approach could shed light on how different disciplines conceptualise ATCs and how systemic factors influence their implementation. Additionally, there is a need for research into the role of families in sustaining ATC use, particularly whether psychoeducation improves long-term engagement. Crucially, structured, evidence-based guidelines are needed to standardise ATC implementation across neurorehabilitation settings. Finally, future studies should expand outcome measures, using quantitative and longitudinal approaches to assess the impact of ATCs and where and how best to implement them using training and ongoing support.

This research underscores that ATC is not a 'fix' for cognitive difficulties. Instead, it should be utilised in conjunction with a broader, psychologically informed approach to neurorehabilitation, one that acknowledges the complexities of recovery, the challenges of adjustment, and the importance of human relationships in life after brain injury. Clinical psychologists have an important role to play in bridging the gap between technology and meaningful, person-centred care, ensuring that ATC is not just something people are given, but something they are supported to use in ways that genuinely improve their lives.

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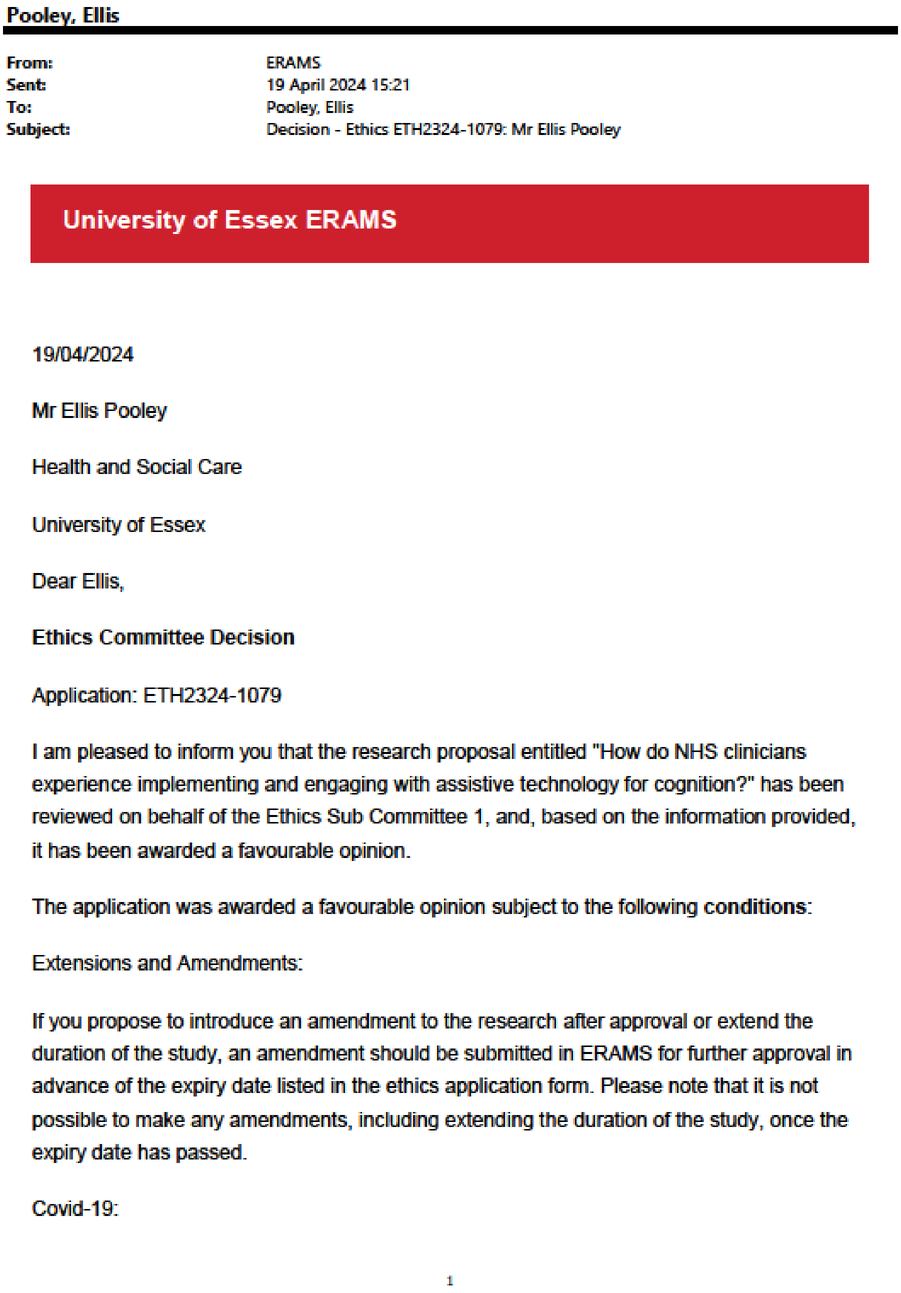
# 7. Appendices

## 7.1. Appendix 1- Ethical approval



**Pooley, Ellis**

**From:** ERAMS
**Sent:** 19 April 2024 15:21
**To:** Pooley, Ellis
**Subject:** Decision - Ethics ETH2324-1079: Mr Ellis Pooley

**University of Essex ERAMS**

19/04/2024

Mr Ellis Pooley

Health and Social Care

University of Essex

Dear Ellis,

**Ethics Committee Decision**

Application: ETH2324-1079

I am pleased to inform you that the research proposal entitled "How do NHS clinicians experience implementing and engaging with assistive technology for cognition?" has been reviewed on behalf of the Ethics Sub Committee 1, and, based on the information provided, it has been awarded a favourable opinion.

The application was awarded a favourable opinion subject to the following **conditions**:

Extensions and Amendments:

If you propose to introduce an amendment to the research after approval or extend the duration of the study, an amendment should be submitted in ERAMS for further approval in advance of the expiry date listed in the ethics application form. Please note that it is not possible to make any amendments, including extending the duration of the study, once the expiry date has passed.

Covid-19:

## 7.2. Appendix 2- Study protocol

# Ethics application

## Project overview

**Title of project**
How do NHS clinicians experience implementing and engaging with assistive technology for cognition?

**Do you object to the title of your project being published?**
No

**Applicant(s)**
Mr Ellis Pooley

**Supervisor(s)**
Prof Andrew Bateman

**Proposed start date of research**
03 Apr 2024

**Expected end date**
13 Jan 2025

**Will this project be externally funded?**
No

**Will the research involve human participants?**
Yes

**Will the research use collected or generated personal data?**
No

**Will the research involve the use of animals?**

No

**Will any of the research take place outside the UK?**
No

## Project details

**Summary of the project**
This research proposes to better understand the experience and barriers in implementing smartphone ACT's consistently. This proposal is part of pre-existing service evaluation that has been approved within St. George's University Hospitals NHS Foundation Trust.

Acquired brain injury is the leading cause of death and disability for people aged 1-40 worldwide. Cognitive problems are common post ABI, often relating to memory and executive functioning, which can have far reaching impacts on independent and quality of life. Extrinsic sources of support are often necessary to support individuals during rehabilitation and reintegration into everyday life, and as technology and smartphones are becoming ubiquitous with modern life, smartphone technology is pragmatic route for assistive technology research. Prior research has established smartphone ACT's are likely to be effective, but high attrition rates, and difficulty adopting their use long term has been highlighted, and consequently, there is a need for further research.

This research proposes to interview clinicians from a neurorehabilitation ward who have experience utilising smartphone ACT's to support patients. The aim of the interviews is to capture the broad barriers and facilitators to clinician's implementation of ACT in a NHS neuropsychological rehabilitation context.. Clinicians within WOCRS utilise a range of ACT's, and so are well placed to provide feedback on the experience of implementing them within rehabilitation. We are curious as to the broad challenges with delivering neuro-rehabilitation in an NHS setting and problems with the current solutions. If unable to recruit sufficient participants from this trust, participants will also be recruited from other teams and services.

Interviews will be transcribed and an indicative thematic analysis would be performed in accordance with Braun and Clark's guidance. It is hoped the results will help researchers, stakeholders, and ACT designers better understand how smartphone ACT's are implemented within the NHS. It is hoped this will support stakeholders to design national guidelines for the use of ACT's within the NHS (which do not currently exist) and the development of more intuitive and supportive ACT technologies to better support ABI survivors.

**Research project proposal**

**Will the participants, either the subjects or the investigators, be involved in any activities that could be considered to be unlawful in the UK?**
No

**If the project is being undertaken outside the UK, will the participants, either the subjects or the investigators, be involved in any activities that could be considered to be unlawful in the country overseas?**
No

## Participant details

**Who are the potential participants?**
Potential participants will be clinicians who work on the Wolfson Outpatient Cognitive Rehabilitation Service (WOCRS) within the St. George's University Hospitals NHS Foundation Trust. They will be recruited as part of a pre-existing service evaluation being run by the trust. Within their role participants must have utilised assistive technology for cognition directly with patients and have been in there role a minim of 6 months. Participants may hold a qualification that confers professional registration, for instance as a nurse or allied health professional, or indeed may not, such as a healthcare assistant.

Although the above will be the primary pool of potential participants, if recruitment is too low, the study will be opened up to other clinicians in other relevant services. The same criteria will apply.

**How will they be recruited?**
This project is part of a pre-existing service evaluation in the the St. George's University Hospitals NHS Foundation Trust. As such, participants will be clinicians directly recruited from this NHS rehabilitation service. Clinicians will be purposefully sampled to recruit clinicians who have use of assistive technology apps for rehabilitation with patients.
Clinicians will be directly contacted via email to explain the study details as well as by word of mouth within the wards by the Clinical Psychologist running the service evaluation project. Snowball sampling will also be used if necessary, and participants will be asked to if they could identify anyone else who may interested in taking part.

**Recruiting materials**
**Will participants be paid or reimbursed?**
No

**If yes, please provide details and justification for this payment.**

**How much will the participants be paid?**

**Could potential participants be considered vulnerable?**
No

**If yes, please explain how the participants could be considered vulnerable and why vulnerable participants are necessary for the research.**

**Could potential participants be considered to feel obliged to take part in the research?**
No

**If yes, please explain how the participants could feel obliged and how any possibility for coercion will be addressed.**

**Will the research involve individuals below the age of 18 or individuals of 18 years and over with a limited capacity to give informed consent?**

No

**Is a Disclosure and Barring Service (DBS) Check required?**
No
**If yes, has the DBS check been completed?**
No

**If your project involves children or vulnerable adults but does not require a DBS check, please explain why.**

## Informed consent

**How will consent be obtained?**
Written

**If consent will be obtained in writing, please upload the written consent form for review and approval.**

**If consent will be obtained orally, please explain why.**

**Please upload a copy of the script that will be used to obtain oral consent.**

**If no script is available to upload please explain why.**

**Who will be obtaining and recording consent?**
I will be obtaining and recording consent.

**Please indicate at what stage in the data collection process consent will be obtained.**
I will be obtaining and recording consent prior to conducting interviews.

**If informed consent will not be obtained, explain why.**

**Please upload a participant information sheet.**

**Have you reviewed the information provided by the REO on participant information and consent?**
Yes

## Confidentiality and anonymity

**Will you be maintaining the confidentiality and anonymity of participants whose personal data will be used in your research?**
Yes

**If yes, describe the arrangements for maintaining anonymity and confidentiality.**
Participants will be assigned a pseudonym. When transcribing the data from the audio recordings, any other identifying details (such as names of services, place names) will be changed or omitted. Any documentation that necessarily contains participant information will be stored separately from the transcripts.

**If you are not maintaining anonymity and confidentially, please explain your reasons for not doing so.**

Confidentiality will only be breached if a participant discloses some information that indicates they or someone else may be at risk. In this case the local adult safeguarding board will be contacted.

## Data access, storage and security

**Describe the arrangements for storing and maintaining the security of any personal data collected as part of the project.**

All data will be stored electronically in secure, password protected files. Participants' names and contact details will be recorded at first contact with the researcher. They will be stored for the purpose of contacting participants to arrange interviews. The pseudonym assigned to each participant to protect their anonymity will also be recorded here so each participant can be linked to their data, so that if they express a wish to withdraw their data within the designated period this can be facilitated. The interview transcripts and relevant participant information such as their age and gender, will be stored separately under the assigned pseudonym. The audio recordings of the interview will be deleted after they have been transcribed. The exception to this will be the consent records which will be retained until no longer required by the university. All other information will be deleted once no longer required.

**Please provide details of all those who will have access to the data.**

The data will only be accessible to myself and my supervisors.

## Risk and risk management

**Risk Assessment documents**

**Are there any potential risks (e.g. physical, psychological, social, legal or economic) to participants or subjects associated with the proposed research?**

Yes

**If yes, please provide full details and explain what risk management procedures will be put in place to minimise the risks.**

There are no apparent immediate risks, however, the act of giving care within a healthcare system such as the NHS can invoke emotive reactions in all clinicians. Whilst it is unlikely the interview will become distressing, there is the potential for challenging experiences or feelings to arise. This will be made clear prior to participants giving their consent. It will be emphasised to participants that they do not have to participate in the research and they can stop the interview at any time without needing to explain why. Participants will be advised that they can withdraw their consent for their data to be used in the study up to one week after the interview is completed.

Prior to conducting the interview, information about the NHS staff wellbeing team will be provided who offer participants can support if they experience distress following or during the interview

**Are there any potential risks (e.g. physical, psychological, social, legal or economic) to the researchers working on the proposed research?**

Yes

**If yes, please provide full details and explain what risk management procedures will be put in place to minimise the risks.**

None apparent, however, being a clinician myself it is possible interviews could bring up challenging and emotive topics that I myself could find distressing. Whilst this feels unlikely, it is a potential risk. I will mitigate this by having regular supervision with my supervisor, as well as peers who are conducting similar research.

**Are there any potential reputational risks to the University as a consequence of undertaking the proposed research?**

No

**If yes, please provide full details and explain what risk management procedures will be put in place to minimise the risks.**

**Are there any other ethical issues that have not been addressed which you would wish to bring to the attention of the reviewer(s) of your application?**

## Dissemination protocol

Research has shown that 75% of UK doctoral theses go unpublished (Cooper & Turpin, 2007). Failing to share research findings limits their application and subsequently slows the progression of further research in the field. This research will be disseminated as widely as is appropriate to maximise its impact.

The researcher intends to publish the findings in a peer-reviewed journal such as Clinical Rehabilitation or Advances in Clinical Neuroscience and Rehabilitation.  However, academic publication is not the only avenue for dissemination. Findings will also be shared with key stakeholders, including Neumind, who collaborated on and supported this project, and St George's. These organisations will also serve as useful connections for identifying future opportunities to present and discuss this research.

Additionally, thesis is a step toward more substantive funded research and the systematic review and qualitative findings will form part of the rationale for a bid to NIHR Research for Patient Benefit on “overcoming barriers to adoption of assistive technology. This thesis will also be made publically available via the Essex University Open Access Research Repository, ensuring access to those who may interested.

## 7.3. Appendix 3- Information sheet for participants

University of Essex

Participant Information Sheet

Project Title: How do NHS clinicians experience implementing and engaging with assistive technology for cognition?

My name is Ellis Pooley and I am a Trainee Clinical Psychologist in the department of Health and Social Care at the University of Essex. I would like to invite you to take part in a research study, which I am conducting as part of my professional Doctorate in Clinical Psychology. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

### What is the purpose of the study?

Acquired brain injury (ABI) is the leading cause of death and disability for people aged 1-40 worldwide. Some of the most common cognitive problems following ABI relate to memory and executive functioning, which can have far reaching impacts on independence and quality of life. Assistive technology for cognition (ATC) is an exciting and growing area from which clinicians can utilize in the rehabilitation of acquired brain injury (ABI). Prior research has established smartphone ATC's are likely to be effective, but high attrition rates, and difficulty adopting their use long term has been highlighted, and consequently, there is a need for further research.

This research is aiming to better understand the experience, barriers, and facilitators in implementing ATC's in rehabilitation from clinicians perspectives, with a particular focus on smartphone ATC's. This research being conducted in collaboration with Neumind, and it is hoped that the study findings will contribute to the development of further ATC's and there implementation in care.

### Why have I been invited to participate?

You have been invited to participate because you a clinician with experience working in neurorehabiliation. During this time you will have had experience supporting patients along there rehabilitation journey and have some familiarity with ATC's.

### What will happen to me if I take part?

You will meet with the researcher (via video call) for an interview. The interview will last approximately one hour. You will have a chance to ask questions and discuss the research before deciding whether or not to take part.

You will be asked some demographic questions. You will then be asked some questions about your experience supporting patients in a neureohabiliation settings and the utilization of ATC's in this setting.

### Do I have to take part?

It is up to you to decide whether or not you wish to take part in this research study. If you do decide to take part you will be asked to provide written consent. You are free to withdraw at any time, without giving a reason. You can request your data is not used in the analysis or write up for up to one week post interview, after which point it will not be possible to withdraw.

### What are the possible disadvantages and risks of taking part?

The research is concerned with your experiences working within a neurorehabilitation and whilst unlikely, could trigger difficult experiences which could be distressing to discuss.

### What are the possible benefits of taking part?

By taking part in this study your knowledge and expertise can be represented in research. This could help in contributing to research that into the application of ATC's in healthcare and neurorehabilitation which could help support services for people with ABI. This is not a guarantee however and there may be no direct benefits of taking part.

**Will my information be kept confidential?**

Participation in the study will be kept confidential. The exception to this would be if you disclose information that suggests you or another person is at risk of harm.

Your data will be stored electronically in secure, password protected files. Your contact information and consent forms with your name on will be stored separately to the interview data, which will be assigned a pseudonym. The audio recordings of the interviews will be deleted after they have been transcribed. The data will only be accessed by myself and my supervisors. The data will be retained for up to 10 years and then it will be deleted. The legal basis for processing the data is your consent.

Your data will be stored in accordance with the principles of GDPR. The Data Controller is the University of Essex University Information Assurance Manager, who you can contact on dpo@essex.ac.uk.

**What will happen to the results of the research study?**

The results of the research will be written up as part the principle investigator's doctoral thesis. This will be retained in the University of Essex thesis repository. It may also be published in a relevant academic journal.

**What should I do if I want to take part?**

If you would like to take part in this study, or ask further questions, please contact Ellis Pooley on ep21485@essex.ac.uk.

Who has reviewed this study?

This study has been granted ethical approval by the University of Essex Research Ethics Sub-Committee 2

### Who should I contact if I have concerns?

**I**f you have any concerns about any aspect of the study or you have a complaint, in the first instance please contact the principal investigator of the project, Ellis Pooley, using the contact details above. You can also contact Ellis's supervisor – Prof Andrew Bateman (a.bateman@essex.ac.uk). If you are still concerned, you think your complaint has not been addressed to your satisfaction or you feel that you cannot approach the principal investigator, please contact Professor Camille Cronin, the departmental director of research for the School of Health and Social Care (camille.cronin@essex.ac.uk), and then Sarah Manning-Press (sarahm@essex.ac.uk), the Research Governance and Planning Manager. Please include the ERAMS reference which can be found at the foot of this page.

### Where can I get support if I feel affected by the issues raised by the study?

Health and social care staff working in England can self-refer to their local Staff Mental Health and Wellbeing Hub, details of which can be found at https://www.england.nhs.uk/supporting-our-nhs-people/support-now/staff-mental-health-and-wellbeing-hubs/.

Samaritans is a free, confidential listening service available 24/7 all year round. They can be contacted by telephone on 116 123, or you can visit their website at https://www.samaritans.org/.

## 7.4. Appendix 3- Consent sheet for participants

Title of the Project: How do NHS clinicians experience implementing and engaging with assistive technology for cognition?

Research Team: Ellis Pooley- Trainee Clinical Psychologist, as supervised by Prof Andrew Bateman- School of Health and Social Care

Please initial box

1. **I confirm that I** have read and understand the Information Sheet dated 31/03/24 for the above study. I have had an opportunity to consider the information, ask questions and have had these questions answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw from the project at any time without giving any reason and without penalty. I understand that any data collected up to the point of my withdrawal e.g. will be destroyed; cannot be withdrawn because it cannot be identified. ☐
3. I understand that the identifiable data provided will be securely stored and accessible only to the members of the research team directly involved in the project, and that confidentiality will be maintained. ☐
4. I understand that my fully anonymised data will be used for a thesis as part of a professional doctorate in clinical psychology. ☐
5. I understand that the data collected about me will be used to support other research in the future, and may be shared anonymously with other researchers. ☐
6. I give permission for the anonymised transcripts to be stored so that they will be available for future research and learning activities by other individuals. ☐
7. I agree to take part in the above study. ☐

Participant Name Date Participant Signature

________________________________ ____________ ________________________________

Researcher Name Date Researcher Signature

________________________________ ____________ ________________________________

## 7.5. Appendix 4- Recruitment poster

University of Essex

## Are you a clinician working in neuro-rehabilitation? Do you use assistive technology?

### What is this study about?

Assistive technology for cognition is an emerging tool which clinicians can use to support neuro-rehabilitation. This study seeks to understand the experience of implementing assistive technology for clinicians in a neuro-rehabilitation setting.

### Why participate?

- Most research has focused on the technology itself, but we recognize that people's support systems are equally vital. By participating, you'll help us explore how these support networks can be optimized to enhance the effectiveness of assistive technologies, ultimately improving the quality of life for those with cognitive challenges

### Who can participate?

- If you work in a neuro-rehabilitation setting.
- If you have at any time utilised a smartphone based assistive technology for cognition in a neuro-rehabilitation context.

### What will happen?

You will be invited to an interview online, led by myself, which we estimate will run between 30-60 minutes. You will also be asked to fill in a brief demographic questionnaire.

If you wish to participate in my research, or have any questions, please contact me: Ellis Pooley: ep21485@essex.ac.uk.

This doctoral research study has been approved by the University of Essex's School of Health and Social Studies Ethics Committee

## 7.6. Appendix 5- Semi-structured interview guide

**Semi-structured interview for clinicians working with assistive technology for cognition**

Can you describe your experience with implementing assistive technology for cognition in your practice within the NHS?

How useful do you feel assistive technology is in supporting service user's neurorehabiliation?

How do you assess the suitability of assistive technology for a client/service user?

How do you perceive the usefulness and acceptance of assistive technology among clients/service users?

What do you think is important in the successful implementation and engagement of assistive technology?

What gets in the way of the successful implementation and engagement of assistive technology? How do you address any barriers?

How do you involve family members/informal caregivers in the process of implementing assistive technology?

How do you think family members/informal caregivers experience utilising assistive technology?

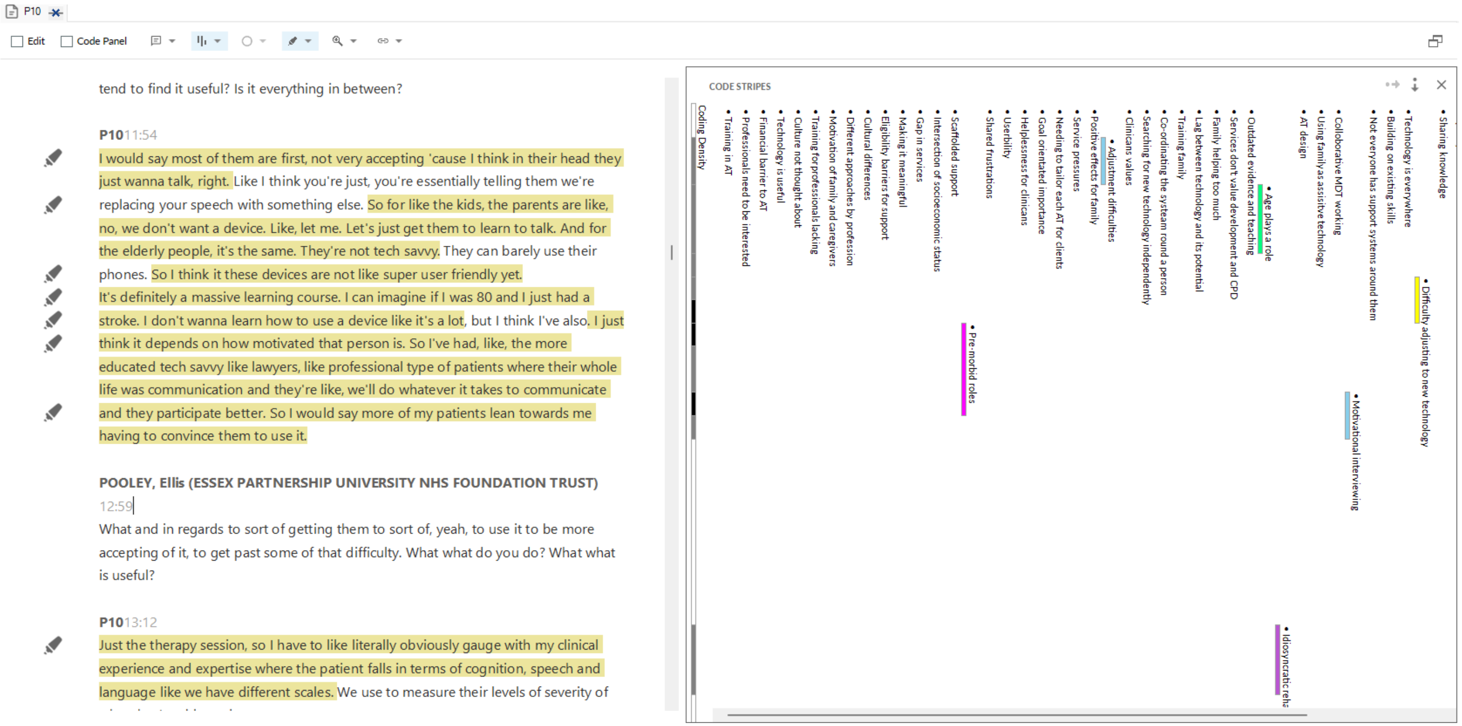
Are there any barriers to family members/informal caregivers getting involved? How are these addressed?

How do you/your team stay updated on advancements and best practices in assistive technology for cognition?

How do you feel the wider team feel about utilising assistive technology in clinical practice?

What improvements in technology, or additional resources, do you think could enhance the implementation and engagement with assistive technology for cognition within the NHS?

## 7.7. Appendix 6- Worked example of the Nvivo coding process



tend to find it useful? Is it everything in between?

**P10** 11:54

I would say most of them are first, not very accepting 'cause I think in their head they just wanna talk, right. Like I think you're just, you're essentially telling them we're replacing your speech with something else. So for like the kids, the parents are like, no, we don't want a device. Like, let me. Let's just get them to learn to talk. And for the elderly people, it's the same. They're not tech savvy. They can barely use their phones. So I think it these devices are not like super user friendly yet. It's definitely a massive learning course. I can imagine if I was 80 and I just had a stroke. I don't wanna learn how to use a device like it's a lot, but I think I've also. I just think it depends on how motivated that person is. So I've had, like, the more educated tech savvy like lawyers, like professional type of patients where their whole life was communication and they're like, we'll do whatever it takes to communicate and they participate better. So I would say more of my patients lean towards me having to convince them to use it.

**POOLEY, Ellis (ESSEX PARTNERSHIP UNIVERSITY NHS FOUNDATION TRUST)**

12:59

What and in regards to sort of getting them to sort of, yeah, to use it to be more accepting of it, to get past some of that difficulty. What what do you do? What what is useful?

**P10** 13:12

Just the therapy session, so I have to like literally obviously gauge with my clinical experience and expertise where the patient falls in terms of cognition, speech and language like we have different scales. We use to measure their levels of severity of

## 7.7 Appendix 7- Supplementary Table A

Search terms used in database searches

| | |
|---|---|
| Population | “acquired brain injur*” OR ABI OR “traumatic brain injur*” OR TBI OR brain injur* OR head injur* OR craniocerebral trauma OR brain damage OR exp stroke |
| Intervention | exp smartphone; smartphone* OR “smart phone” OR “i phone*” OR iphone* OR “smart technolog*” OR assistive technology OR cognitive prosth* |
| Outcome | Memory OR "executive function" OR "executive dysfunction" |

## 7.8 Appendix 8- Supplementary Table B

Quality of methodology of Class I studies assessed using the PEDro-P and PEDro+ scale

| Study | Eligibility criteria specified (not included in | Random allocation | Concealed allocation | Intervention groups similar | Participants blinded | Therapists blinded | Assessors blinded | Retention of > 85% of participants | Intention to treat analysis H Withdrawal and dropout | Between group statistical comparisons | Point and variability measures | PEDro- total | Treatment replicability | Treatment fidelity | PEDro+total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jamieson et al., 2022 | Y | Y | N | Y | N | N | N | N | Y | Y | Y | 6 | Y | N | 7 |
| Ramirez-Hernandez et al., 2021 | Y | Y | Y | Y | N | N | Y | Y | Y | Y | Y | 9 | Y | Y | 11 |
| Andreassen et al., 2020 | Y | Y | Y | Y | N | N | N | Y | Y | Y | Y | 8 | Y | N | 9 |
| Scullin et al., 2021 | Y | Y | Y | Y | N | N | Y | Y | Y | Y | Y | 9 | Y | N | 10 |

## 7.9. Appendix 9- Supplementary Table C

Quality of methodology Class II&III- Quality of Methodology Criteria Ratings on the Risk of Bias in N-of-1 Trials (RoBiNT) scale

| Study | Internal validity | | | | | | | Subtotal | | External validity | | | | | | | Subtotal | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Design with control | Randomization | Sampling of behaviour | Blinding of people | Blinding of assessor | Inter-rater agreement | Treatment adherence | | Baseline characteristics | Therapeutic Setting | DV | IV | Raw data record | Data Analysis | Replication | Generalization | | |
| Vasquez et al., 2023 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 6 | 8 |
| Ertas-Spantgar, 2022 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 7 | 9 |
| Bos et al., (2017) | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 4 | 1 | 0 | 2 | 2 | 2 | 1 | 0 | 0 | 8 | 12 |
| Chang et al., 2018 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 2 | 1 | 2 | 1 | 0 | 9 | 12 |
| Ferguson, Friedland, Woodberry, 2015 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 4 | 0 | 1 | 2 | 2 | 1 | 2 | 2 | 0 | 10 | 14 |
| Cruz et al., 2016 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 5 | 1 | 1 | 1 | 1 | 2 | 2 | 0 | 0 | 8 | 13 |
| Annese et al 2023 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 12 | 13 |
| Bos et al., (2017) | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 4 | 1 | 0 | 2 | 2 | 2 | 1 | 0 | 0 | 8 | 12 |