Developing Inclusive and, Remote Out-Patient Neurorehabilitation Services through the Use of Digital Technology and large language models

1. Background of the challenge

Neurorehabilitation is a health strategy that aims to enable people experiencing or likely to experience neurological disorders to achieve and maintain optimal functioning including in mobility, vision, hearing and cognition. Neurological issues, including stroke and dementia are significantly increasing globally, supported by limited clinical resources, requiring solutions that address these problems in a highly scalable, cost effective manner. The use of digital technology and large language models offer significant opportunities to provide a more inclusive service, maximising the impact of remote neuro-management and community care services. In this proposal, three key challenges are highlighted in the often neglected aspect of neurorehabilitation, diagnosis and management.

Problem 1: Addressing Equity, Diversity and Inclusion (EDI) in Neuro-Diagnosis and Treatment

The three groups who frequently face limited access to neurorehabilitation services are (i) individuals living in remote areas, (ii) ethnic and linguistic minorities and (iii) individuals with varying speech and/or motor abilities. The number of people diagnosed with neurodegenerative diseases in the UK is on the rise primarily due to an increasing ageing population. Large language models offer highly automated solutions to personalise support and rehabilitation services, enabling patient care outcomes to be optimised.

Rural populations: Neurorehabilitation for rural populations is particularly challenging due to a lack of local access to neuro-specialist rehabilitation and poor social and community care services. As a result, getting neuro-diagnosis and treatment often requires patients to travel long distances. The significant cost and time burdens on patients to access care often results in patients opting out of neurorehabilitation treatment.

Linguistic and ethnic minority backgrounds: Diagnosis of cognitive abilities for those with neurological impairment rely heavily on language recognition and ability. Cultural factors may further bias cognitive scores, leading to an overestimation of cognitive impairment (Parker & Philp, 2004; Low et al., 2012). As a result, diagnosis of cognitive abilities among linguistic and ethnic minorities is inaccurate and oftentimes is a misinterpretation of their cognitive abilities (Ng et al., 2018).

Individuals with Disabilities: Meeting the needs of neurologically impaired patients with varying motor/speech abilities has also been challenging (Schmitz-Peiffer et al., 2022). Numerous diagnostic measures (e.g., cognitive or language functions) require unimpaired speech and motor abilities. As a result, testing patients with severely impaired speech and/or motor abilities is nearly impossible and will result in poor performance. Despite this, the impact of motor and speech tasks on neurological diagnosis cannot be eliminated from diagnostic tools.

Problem 2: Poor Patient Management and Fragmented Integration Between Health and Social care

For many neurological conditions, self-management is the key element to recovery and improving patients' autonomy. However, according to the Neurological Alliance (2018) report only 15% neurology patients currently have care plans, with 82% patients have never been offered a care plan. Patients were often given diagnosis of their conditions without a proper care plan communicated to them or their families/carers. As a result, patients are hospitalised longer than they should whilst waiting for rehabilitation care plans and/or assignment of social care. In reality for many acute neurology patients, rehabilitation can be done at home with little to no supervision; this can free up a huge number of hospital beds for patients that are in need of care.

In addition, there is a significant number of patients waiting to be referred to a neurorehabilitation specialist, social care workers and community clinics. Currently used referral triage system is not standardised across the NHS Trusts causing unnecessary referrals, backlog of patients and greater demand on neurology departments. Effective usage of data visualisation could greatly improve communication between practitioners and patients. The use of machine learning and mathematical modelling techniques could

provide rapid auto-triage of patients, predict patients' recovery outcomes for care plans, personal AI assistants and personalised scaffolding for rehabilitation, and resulting in more effective care plans.

Problem 3: National shortage and inefficacy of neurorehabilitation services

Despite the benefits of neurorehabilitation services to support neurological disability, ineffective healthcare systems and lack of expertise (199 therapists and <50 occupational therapists per million of the population) are some of the reasons for the challenges faced in optimal delivery of rehabilitation services (Gandhi et al., 2021). The World Health Organisation (WHO) reported that there is a mounting shortage of rehabilitation personnel (quantity and quality) and uneven distribution of resources especially between urban and remote areas globally. On top of that, the NHS highlighted two main national challenges in neurorehabilitation services, (i) fragmented services between different departments (i.e., neurology and rehabilitation) and (ii) delay in primary and secondary care resulting in delay in diagnosis and patients receiving appropriate treatments.

The key to addressing these growing issues in neurorehabilitation is the adoption of technology to alleviate burden on the healthcare system. A few potential solutions include digitalising referral pathways between primary and specialist care, automating cognitive diagnosis and providing alternatives for at-home, remote rehabilitation therapy. In addition, employment of mathematical modelling has potential to support better understanding of current and future needs for neurological healthcare service provision.

2. Information available to help address the challenge

a) Literature journals on topics such as: cross-cultural cognitive assessment, remote usage of cognitive tests and motor/speech independent cognitive assessment, usage of ML/AI in neurorehabilitation
b) NHS National Challenges Report
c) Pen and paper cognitive test batteries used within NHS settings
d) Digital tools currently being used in neurology and neurorehabilitation departments

3. Questions to tackle during the meeting

In order to find solutions for the challenges above, we wish to find answers to the following questions:

Emerging technologies	Deployment and commercialisation
1. How can technology such as ML/AI assist clinicians in providing remote, community care services? 2. How can AI support "information transformation" or "content matching" in order to present information flexibly to support patients specific needs 3. Can other technologies (e.g. logic programming) create synergistic effects to LLM performance, reducing known LLM risks such as hallucinations	1. What are the route to market options for this type of product? 2. How can the UK health ecosystem support the testing and deployment of remote rehabilitation services. 3. What is a sensible roadmap for the different stages of product development to maximise impact on a national scale?

References

Gandhi, D. B. C., Kamalakannan, S., Chockalingam, M., Sebastian, I. A., Urimubenshi, G., Alim, M., Khatter, H., Chakraborty, S., & Solomon, J. M. (2021). Expert consensus for in-hospital neurorehabilitation during the COVID-19 pandemic in low- and middle-income countries. *Wellcome open research*, *6*, 130. https://doi.org/10.12688/wellcomeopenres.16715.1

Low, L. F., Harrison, F., Kochan, N. A., Draper, B., Slavin, M. J., Reppermund, S., ... & Brodaty, H. (2012). Can mild cognitive impairment be accurately diagnosed in English speakers from linguistic minorities? Results from the Sydney Memory and Ageing Study. *The American Journal of Geriatric Psychiatry*, *20*(10), 866-877.

Ng, Kok Pin, et al. "The influence of language and culture on cognitive assessment tools in the diagnosis of early cognitive impairment and dementia." *Expert review of neurotherapeutics* 18.11 (2018): 859-869.

Neurological Alliance (Ed.). (2018). (rep.). *The long term plan for the NHS: Getting it right for neurology patients*. Available online from: https://www.neural.org.uk/assets/pdfs/2018-08-long-term-plan-for-nhs.pdf

NHS. (2019). (rep.). *Transforming elective care services neurology*. NHS England and NHS Improvement. Available online from https://www.england.nhs.uk/wp-content/uploads/2019/07/neurology-elective-care-handbook.pdf.

Parker, C., & Philp, I. (2004). Screening for cognitive impairment among older people in black and minority ethnic groups. *Age and ageing*, *33*(5), 447-452.

Schmitz-Peiffer, H., Aust, E., Linse, K., Rueger, W., Joos, M., Löhle, M., Storch, A., & Hermann, A. (2022). Motor-Independent Cognitive Testing in Motor Degenerative Diseases. *Journal of clinical medicine*, *11*(3), 814. https://doi.org/10.3390/jcm11030814

Turner-Stokes, L., Williams, H., Bill, A., Bassett, P., & Sephton, K. (2016). Cost-efficiency of specialist inpatient rehabilitation for working-aged adults with complex neurological disabilities: a multicentre cohort analysis of a national clinical data set. *BMJ open*, *6*(2), e010238.