**Introduction:**

Sensory motor deficiency may occur in individuals who have suffered nervous system damage, such as brain or spinal cord injuries, resulting in hemiparesis. This condition can significantly hinder their ability to carry out daily activities. Therefore, the recovery process becomes essential in restoring their sense of touch and proprioception, as it plays a vital role in improving their overall lifestyle.

Motor dysfunction related to the nervous system can stem from various causes, encompassing cerebral palsy (Poitras *et al.*, 2021), spinal cord injury, multiple sclerosis (Adamovich *et al.*, 2009), traumatic brain injury (Subramanian *et al.*, 2022), among others. Nevertheless, the primary and prevailing cause of sensory motor dysfunction, particularly affecting the upper limbs, remains stroke (Anwer *et al.*, 2022).

With the global aging of populations, the incidence of strokes is on the rise, leading to an increased demand for rehabilitation services from healthcare organisations. Interestingly, there has also been a noticeable increase in stroke occurrences among adults aged 20 to 64, necessitating additional support for individuals experiencing the consequences of strokes (Katan and Luft, 2018). Importantly, recent studies have revealed a decline in the mortality rate of strokes, primarily due to advancements in healthcare, including improved medicines and better post-stroke care (Lackland *et al.*, 2014; Seminog *et al.*, 2019). However, this positive trend places a further strain on healthcare organisations as they are required to maintain accessible care for individuals who have suffered from a stroke (Coupar *et al.*, 2012). As the demand for rehabilitation services increases beyond hospitals, healthcare providers are progressively turning to home-based rehabilitation interventions. Consequently, this approach results in a decrease in patients' hospital stay duration. This shift aims to accommodate the growing need for rehabilitation while allowing patients to receive necessary care and support in the comfort of their homes (Coupar *et al.*, 2012).

When a person experiences a stroke, their brain's neuron cells are deprived of oxygen and glucose, leading to their death. Among these neurons, those within the motor cortex region play a crucial role in facilitating successful motor control of the upper limbs. Consequently, any damage to neurons in this area results in disrupted communication between the brain and the body, leading to upper limb hemiparesis (Chae *et al.*, 2002). It’s worth noting that neuronal damage can continue to occur for days after the stroke has occurred, this emphasises the importance of starting and maintaining recovery intervention process (Puig, Brenna and Magnus, 2018; Teasell and Mbbs, 2018). For effective rehabilitation, the damaged neurons must undergo regeneration and reorganisation to create new functional connections, which is referred to as brain plasticity. Both animal and human models have demonstrated that engaging in appropriate upper-limb exercises promotes increased brain plasticity in the activated brain regions. This heightened plasticity, in turn, leads to improved motor control and learning (Daly and Ruff, 2007).

Achieving the best recovery for the hemiparetic upper limb after a stroke demands significant dedication to a rehabilitation program from patients. However, it is common for patients to struggle with maintaining commitment to their program once they are discharged from the hospital (Toh, Chia and Fong, 2022). Recent evidence indicates that consistent home-based therapy yields considerable improvements in recovery compared to traditional clinical-based therapy. Moreover, this approach has shown promising results in enhancing the quality of life for stroke patients (Toh, Chia and Fong, 2022). Therefore, encouraging and supporting patients in adhering to their-home based rehabilitation program is extremely important to ensure optimal recovery.

More recently, researchers have been exploring and integrating technology into home-based rehabilitation approaches. It is crucial for stroke patients to actively participate in their rehabilitation with intensity and repetition to achieve the best possible recovery (Teasell and Mbbs, 2018). Virtual Reality (VR) offers a valuable solution to enhance patient engagement and create a safe, multisensory environment that can be utilised at home, providing instant feedback, for patients and clinicians. VR technology presents an opportunity for patients to immerse themselves in an interactive environment, where they can perform specific exercises tailored to their individual needs in a concentrated and repetitive manner. This stimulation of neuroplasticity through VR supports the recovery process, helping patients make significant progress in their rehabilitation journey (Saposnik, Levin and null, 2011).

The impact of VR on patients' recovery has been the subject of various studies. While some research, such as that by (Laver *et al.*, 2017), has shown no significant effect of VR in rehabilitation, other studies, like the one conducted by (Saposnik, Levin and null, 2011) have demonstrated that integrating VR into conventional upper limb rehabilitation can substantially enhance a patient's motor control. Additionally, VR offers several other advantages, including increased accessibility due to lower cost and portability of the technology. Its use does not require the constant presence of specialists, and remote feedback and improvement by physiotherapists can be facilitated. These factors collectively reduce the burden on healthcare organizations in providing rehabilitation services (Saposnik, Levin and null, 2011).

As VR continues to evolve, further research and advancements will likely refine its role and efficacy in stroke rehabilitation. One promising area of investigation involves the integration of robotics and haptic feedback into rehabilitation techniques. By utilising robotics and haptic feedback, patients can interact with a diverse range of objects and exercises, experiencing different properties that can be tailored to their specific needs (Turolla *et al.*, 2013; Yeh *et al.*, 2017). This innovative approach holds tremendous potential in providing a more immersive and customized rehabilitation experience, ultimately contributing to improved outcomes for stroke patients. Importantly, repetition of simple exercises does not always improve neural plasticity. However, incorporating multiple forms of feedback including visual, auditory, force, touch, and proprioception, is proposed to improve motor control in patients with upper limb impairment (Maris *et al.*, 2018). The implementation of VR and haptic feedback offers clinicians a tool to incorporate multi-modal feedback into rehabilitation exercises tailored to the patients' skill level, optimising neural plasticity and the rehabilitation process (Plautz, Milliken and Nudo, 2000; Yeh *et al.*, 2017).

[Include a figure demonstrating haptic technology impact on the brain]

As the significance of haptics and VR in upper limb rehabilitation becomes increasingly evident, this project aims to integrate the force dimension delta haptic device [insert citation] and VR technology to develop a safe and productive environment for patients engaging in upper-limb rehabilitation exercises. By combining haptics and VR, the aim is to present a novel technique to facilitate a successful recovery process while reducing the strain on health care organisations providing rehabilitation services. It will also demonstrate that patients will be able to experience a more immersive and personalised rehabilitation journey, enhancing their engagement and promoting better rehabilitation outcomes outside of hospitals or clinics. This approach holds the potential to improve stroke survivors with upper-limb impairments quality of life and allow them to regain independence performing day to days tasks.

**Methodology:**

* Look at haptic software design
* Diagrams for design of haptic interface –
  + chapter 11 (engineering haptic devices)
  + P.g 91: Kinesthetic interfaces 4.6.3

**Things to consider:**

* Factors influencing haptic perception (EHD – 57)
* Evaluation of haptic systems (EHD – 587)
* Advantages and Disadvantages of parallel mechanism (force dimension) (EHD – 272)
  + Parallel mechanical design – 3DoF