Executive Summary

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1. **Title of the Project:** Robotic Exoskeleton and Augmented Reality Virtual Reality Technologies in Rehabilitation for upper limb disability

2. Date of Start of the Project: 1 October 2022 (Ref: INAE/121/AKF/38)

3. Aims and Objectives:

1. To design and develop a device for Augmented Reality Virtual Reality (ARVR) platform for rehabilitation of distal upper extremities in patients with stroke for home-based settings
   - Design and optimize the patient-specific joystick device for wrist and fingers according to the movements used in activities of daily living (ADL)
   - Optimize the ARVR tasks according to ADL
   - Optimization of these developed ARVR tasks based on spasticity score for a specific group of patients to assess the variability of the clinical effect of ARVR
   - Aesthetics and the portability of the device will be improved
2. An android app will be designed for remote monitoring of patients' rehabilitation at home-based settings
3. A randomized clinical-trial to evaluate the therapeutic impact of designed VR platform and compare it with standard physiotherapy control.
   - Clinical data acquisition on patients with stroke (n=60) and subjective and objective outcome measures.
   - Evaluation of its clinical impact by comparing pre- and post- outcome measures.

4. Significant achievements (not more than 500 words to include List of patents, publications, prototype, deployment etc)

International Journal Publications: 3

1.) Banduni, O., Saini, M., Singh, N., Nath, D., Kumaran, S.S., Kumar, N., Srivastava, M.V.P., **Mehndiratta, A.** (2023). Post-Stroke Rehabilitation of Distal Upper Limb with New Perspective Technologies: Virtual Reality and Repetitive Transcranial Magnetic Stimulation—A Mini Review. *J. Clin. Med.* 12(8), 2944. doi:10.3390/jcm12082944. **Impact Factor: 4.964.**

2.) Singh, N.; Saini, M.; Kumar, N.; Padma Srivastava, M.V.; **Mehndiratta, A.;** (2023). Individualized closed-loop TMS synchronized with Exoskeleton for modulation of cortical

excitability in patients with Stroke: A Proof-of-Concept Study. *Front. Neurosci.* 17:1116273. doi: 10.3389/fnins.2023.1116273. **Impact Factor: 5.152.**

3.) Nath, D.; Singh, N.; Saini, M.; Banduni, O., Kumar, N., Padma Srivastava, M.V., **Mehndiratta, A.;** (2023). Clinical potential and neuroplastic effect of targeted virtual reality based intervention for distal upper limb in post-stroke rehabilitation: a pilot observational study. *Disability and Rehabilitation*. doi:10.1080/09638288.2023.2228690. **Impact Factor: 2.439.**

Prototype development:

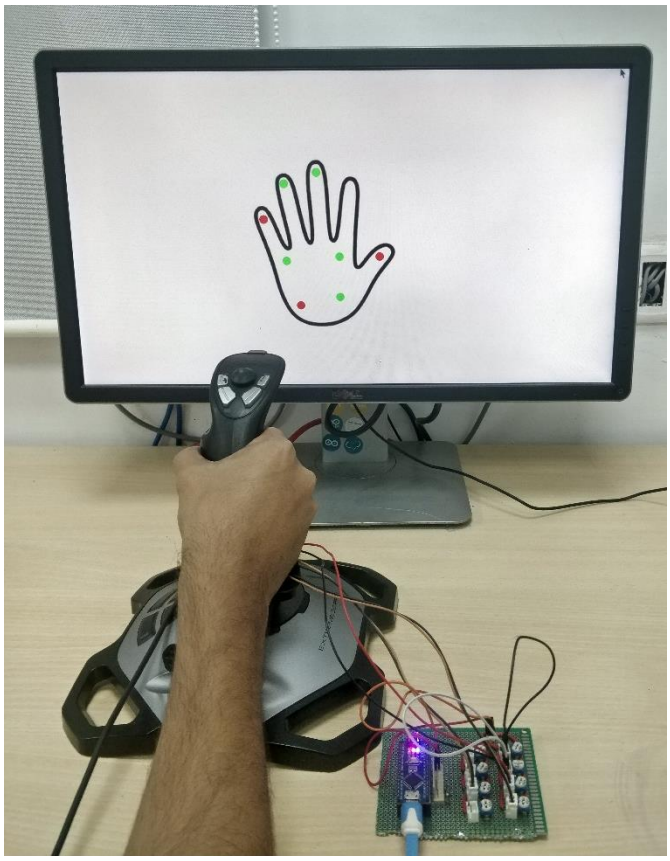

Figure: Force sensors FSRs placed on /joystick with the healthy hand placed on joystick and PCB

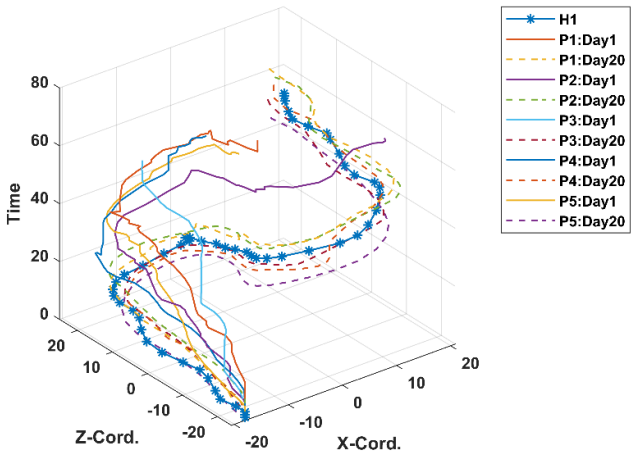

Figure: showing the 3D trajectory comparisons of a representative healthy subject (H1), and the trajectories of the patients at day 1 and day 20 of the therapy obtained for CE3-L1. At day 20, the trajectories of the patients appeared to be similar to that of a healthy subject.

Summary:

The literature review around this niche area of virtual reality, it's application in distal joints rehabilitation and the neurophysiological basis and mechanism of action, the available state of art and the lacunae in the literature, lack of standardization of VR protocols, its pairing with non-invasive brain stimulation and the barriers and ways to overcome it towards motor recovery been completed and published in Journal of Clinical Medicine.

The specific force sensors have been explored and finalized along with the way of calibration with different force and preliminary design of force sleeves over the joystick has been done and taken feedback from healthy subjects (n=3). The preliminary GUI along with the customized PCB hardware has been developed for this hand grip measurement of patients. The hand grip and dexterity measurement device will encompass a meticulously engineered sleeve, featuring a sophisticated array of strategically positioned pressure sensors. These sensors have been meticulously placed to faithfully replicate the natural human grip when holding an object. This design serves as a reliable and comprehensive tool for assessing both hand grip strength and dexterity. Furthermore, this approach empowers therapists to recommend personalized exercise routines, custom-tailored to each patient's unique needs and goals. This level of personalization not only enhances the effectiveness of rehabilitation but also fosters greater patient engagement in the recovery process. Ultimately, this comprehensive and adaptable system promises to significantly advance the field of hand grip and dexterity assessment and rehabilitation.

The battery of virtual reality tasks has been developed and given therapy to five patients (n=5) after the finalization of intervention protocol. The optimization of these VR tasks has been done for a special case patient n=1 (with no spasticity and no activities training) and the therapy has been given.

5. Concluding remarks

1. The prototype design for the novel force sensitive joystick is in development. Patients feedback for the same are being sort with the help of neurologist and physiotherapist at Department of Neurology, AIIMS New Delhi.
2. The ARVR module for patients with difficulty in ADL is being improvised for individual patients. The same will be generalized for larger patient cohort for the clinical study.
3. Feedback from stakeholders including doctors (n=1), physiotherapists (n=2), healthy subjects (n=3) and patients with stroke (n=5) has been taken at various stages of the development.