LifeTech Madeira: changing the paradigm in quality-of-life technologies research in Madeira

Abstract

In June 2022, a collaboration protocol between the Dean of the University of Madeira, Professor Sílvio Moreira Fernandes and the Secretary of Civil Protection and Health, Dr. Pedro Ramos, was signed, giving rise to the Quality-of-Life Technologies Center of Madeira - LifeTech. The goal of LifeTech is to develop technology to improve the quality of life after disability through illness or ageing.

The origins of LifeTech stem from over ten years of collaboration between the research group NeuroRehabLab associated with the University of Madeira/ARDITI and the Department of Physical Medicine and Rehabilitation of the Regional Health System of Madeira (SESARAM). Our experience is that there is a mutual benefit in joining health professionals with researchers with a background in engineering into a "thought box" directed to problem-solving.

Lifetech adopts an interdisciplinary approach centered on the pillars of neuroscience, clinical practice, human-machine interaction, and virtual reality. Clear communication leads to a better understanding of the potential and limitations on either side. Our approach is to bridge the gap between basic research and clinical practice in such a way that research can be directed to solve immediate clinical situations and shorten the process in which the developed technology can benefit the target population.

This collaboration gave rise to multiple technological systems that have been clinically validated. For instance, several virtual reality (VR) instruments developed for cognitive rehabilitation were able to make the transition to clinical practice. These instruments include Reh@city, Reh@task and the NeuroRehablab task generator (Faria et al., 2018; Faria & Badia, 2015; Vourvopoulos et al., 2014). Globally, patients have shown improvement in neuropsychological assessments and have reached the goals set out. Another important focus of the collaboration has been rehabilitation after stroke. We developed a Brain-Computer Interface (BCI) system called NeuRow in which an avatar can be controlled through the imagination of movement (Vourvopoulos et al., 2019). The simple imagination of movement is a mental exercise that activates neurons in a similar way to actual movement, and the BCI-VR system allows feedback. The scope of LifeTech extends further from interactive tables for motor rehabilitation and social engagement (Pereira et al., 2019) to exergames designed to be a motivating and safe way of exercise for the elderly and disabled (Gouveia et al., 2019). Finally, for phantom pain after lower-limb amputation, a VR-based prototype was developed using electrophysiology and providing mirror treatment. Ongoing projects such as the FCT-funded BRaNT: Belief Revision applied to Neurorehabilitation Therapy - a tablet-based cognitive rehabilitation tool - are undergoing the process of validation within the cognitive rehabilitation unit of

SESARAM with expert support from a neuropsychologist (Spínola et al., 2021). The last project under the Center's umbrella capitalizes on recent evidence of early use of an eye-tracking device in stroke patient upper limb motor rehabilitation. In this sense, eye movements are detected and translated into an avatar's movement (Modroño et al., 2020). Other efforts, such as Musiquence - a cognitive stimulation tool for dementia – could be integrated into the repertoire of treatment options and studied further, for example, in acquired brain injury (Andrade Ferreira et al., 2019).

1. Introduction

This paper aims to provide an overview of the structure, projects, history, and purpose of the Quality-of-Life Technologies Center of Madeira - Lifetech. The Center officially exists since June 2022, after the signing of the collaboration protocol between the Dean of the University of Madeira, Professor Sílvio Moreira Fernandes and the Secretary of Civil Protection and Health of Madeira, Dr. Pedro Ramos. The purpose of LifeTech is to develop technology to improve the quality of life after disability through illness or ageing.

The signing of the protocol was an important milestone as it laid the institutional framework for the development of the Center. However, the groundwork has been established from ten years of collaboration between the University of Madeira/ARDITI and the Department of Physical Medicine and Rehabilitation of the Regional Health System of Madeira (SESARAM).

The consolidation of resources of the two institutions helps the Center to help patients who benefit from new rehabilitation and assistive technology approaches. In turn, it provides an environment to promote research in a close clinical /academic context, leading to quality publications with international visibility.

2. Lifetech Framework

The projects included in Lifetech require technology development to improve quality of life. The technology can overlap in three domains: rehabilitation tools that help recover function; assistive devices that can compensate for lost function; technology with a palliative quality after life-changing events and/or conditions.

Lifetech has two poles: academic and clinical. The clinical side is integrated and centered in the Physical Medicine and Rehabilitation Department of the Regional Health System of Madeira (SESARAM) whilst the academic side is centered in the University of Madeira in an intricate work model with NeuoRehabLab of ARDITI.

The two poles have an official monthly meeting. This meeting follows a flexible structure: Introductions; summary of the previous meeting; updates; opening for comments, suggestions and/ or new ideas; assessment of topics based on the last meeting and updates; review of an action plan for the following meeting. This allows for inter-institutional macroplanning and most importantly, brainstorming in an open dialogue setting, whilst each individual project of the Center has, in turn, its own work plan and coordination.

2.1 Clinical Framework

SESARAM is the regional Health system of Madeira Island, run through a corporate public enterprise model. It comprises both Secondary and Primary Care as well as providing support to the region's continued care network. Hospital care is provided by the Central Hospital of Funchal, which is comprised of three articulated and complementary hospitals: Dr. Nélio Mendonça Hospital; Marmeleiros Hospital; João de Almada Hospital. The administrative services are centered in Dr. Nélio Mendonça Hospital.

The clinical pole of Lifetech is managed through the Physical Medicine and Rehabilitation Department, which is centered in Dr. Nélio Mendonça Hospital. The Department is branched throughout the primary healthcare centers and continued care network. Most of the patient flow is outpatient Care in which patients are treated during the day before going home. At Dr. Nélio Mendonça Hospital, besides outpatient Care the Department provides support to the patients admitted in different wards of the Hospital. Coordination of the rehabilitation program in Primary Care and the Continued Care network is done through Dr. Nélio Mendonça Hospital. Patient flow is as follows. Patients are referred to the Department through the SESARAM computer system either as an external consultation (patient is at home) or an inpatient consultation (patient is admitted to Nélio Mendonça Hospital). All referrals for external consultations are reviewed by the Department Director and scheduled a consultation with one of the Physiatrists. The physiatrist assesses the patient's medical and rehabilitation needs and coordinates a rehabilitation program. A prescription of the patient's rehabilitation need is then sent to the respective coordinator: physiotherapy, occupational therapy and/or speech therapy, who allocates a therapist according to specificities. All internal consultations are seen by the respective physiatrist designated monthly. The physiatrist reviews the patient and articulates the rehabilitation program with therapists.

The Lifetech team consists of a Clinical Director specialized in Physical Medicine and Rehabilitation, a Vice-Director in case of the absence of the Director, Coordinators of cognitive rehabilitation, physiotherapy, occupational therapy and speech therapy and a coordinator of patient logistics. The role of the clinical team includes:

Clinical studies:

- Collaboration in research protocol design;
- Articulation with the ethics committee;
- Articulation with SESARAM research department and scientific committee;
- Patient recruitment;
- Implementation or supervision of the experimental intervention;
- securing conventional treatment in control groups;
- Clinical assessments of patients in control and experimental groups;

Coordination:

- Meetings with the academic pole;
- Liaison with other departments involved in the research study;
- Coordination with other departments for complementary exams, such as imaging;

Needs assessment:

- Feedback on limitations of experimental interventions;
- Provide therapeutic targets for the development of future projects;

Outreach:

- Training of health professionals on the use of the system developed by Lifetech;
- Meetings and securing clear communication with the academic pole;
- Provide support to promote initiatives of health professionals in SESARAM interested in collaborating with Lifetech;

Logistics:

- Patient logistics (transport, schedules to not interfere with other treatments/consults);
- Allocating space for experimental interventions to take place;

2.2 Academic Framework

The academic pole of LifeTech is currently based on the work by the NeuroRehabLab, an interdisciplinary research group of the University of Madeira that investigates the intersection of technology, neuroscience, and clinical practice to find novel solutions to increase the quality of life of those with special needs. The NeuroRehabLab's focus on improving the quality of life of those with special needs is an area of research that has gained increasing importance in recent years. As the population ages and the prevalence of chronic illnesses such as stroke, Parkinson's disease, and multiple sclerosis continues to rise, there is a growing need for innovative solutions to help people recover their motor and cognitive function.

The interdisciplinary approach of the NeuroRehabLab is particularly well-suited to addressing these challenges. By bringing together experts from different fields, including neuroscience, clinical practice, and technology, the group is able to develop a comprehensive understanding of the complex issues involved in rehabilitation. This enables them to develop more effective interventions that can have a meaningful impact on the lives of those with special needs.

One of the key strengths of the NeuroRehabLab is their focus on non-invasive and low-cost technologies. By using tools such as Virtual Reality, Serious Games, and Brain-Computer Interfaces, the group is able to provide rehabilitation interventions that are more accessible and affordable than traditional approaches. This is particularly important in regions where access to healthcare is limited or where resources are scarce.

The NeuroRehabLab's affiliation with the Agência Regional para o Desenvolvimento da Investigação, Tecnologia e Inovação – ARDITI and the NOVA Laboratory for Computer Science and Informatics excellence center also provides them with access to a wealth of expertise and resources. This enables them to collaborate with other researchers and institutions, as well as to leverage cutting-edge technologies and methodologies in their work.

The Lifetech team consists of an Academic Director that is affiliated with the Universidade da Madeira, and a team of researchers from the same institution as well as the NeuroRehabLab research group. Collaboration with LifeTech is open to all the academic community. The role of the academic team includes:

Clinical studies:

- Development of technological solutions that address real-world problems;
- Collaboration in research protocol design, ethics and clinical aspects;
- Implementation of the experimental intervention;
- Ensuring compliance with ethical and safety guidelines;

Coordination:

- Meetings with the clinical pole;
- Funding development;
- Pursue of basic and applied research strategies;
- Management of project budgets and timelines;

Outreach:

- Scientific publications;
- Public communications with the community (at the reginoal, national and international level);
- Organization of open doors and demo events;
- Provide support to promote initiatives of the academia in UMa interested in collaborating with Lifetech;

Logistics:

- Equipment logistics including design and transportation;
- Coordination with clinical pole;
- Maintaining and updating lab facilities and equipment;

In addition to the above-mentioned roles, the academic team also plays a key role in mentoring and training the next generation of researchers. This involves supervising graduate and undergraduate students, as well as providing opportunities for postdoctoral researchers and visiting scholars to gain valuable research experience.

Furthermore, the team also engages in collaborative projects with other research institutions, both nationally and internationally, to foster knowledge exchange and advance the field of Lifetech. By working with experts from diverse backgrounds and disciplines, the LifeTech is able to stay at the forefront of research and develop innovative solutions to complex problems.

3. Lifetech Projects

3.1 Cognitive Rehabilitation

3.1.1. Clinical Implementation - Cognitive Rehabilitation Program

Figure 1: Cognite rehabilitation set up in Physical Madeicine and Rehabilitation Service of SESARAM

This program was developed to support patients in the subacute phase of acquired brain injury. It consists in integrating components of neuropsychology into the multidisciplinary rehabilitation approach. The program consists of an initial neuropsychological assessment to characterize and quantify cognitive dysfunction. The intervention consists of a twelve-week program. The intervention takes place in three domains:

1. Compensatory interventions: Helping the patient become aware of his difficulties; training compensatory mental techniques, teaching behavioral strategies such as using cues and reminders.
2. Restorative Interventions: This consists of general and domain-specific interventions. General intervention includes pharmacological intervention by the physiatrist and/or aerobic exercise organized through the physiotherapist. The domain-specific intervention uses virtual reality stimulation systems to train specific cognitive domains (attention, concentration, executive functions, memory, language, visuospatial skills, abstraction, calculation, and orientation) developed by the collaboration Neurorehablab/SESARAM. These systems include Reh@city, Reh@task and the NeuroRehablab task generator [1–3].
3. Educational interventions: Integrating the family in support of the patient. Helping family and caregivers better understand the patient's dysfunction, how it relates to their behavior, and how to approach it.

The program began in 2019. To date 27 patients have been treated. Each patient is treated for in 24 sessions with a duration of one hour each over a three month period. Patients undergo a neuropsychological assessment at the beginning and end of their three month period which has shown improvements in most cases. Patients also establish goals at the

beginning of their program which are assessed by the goal attainment scale (GAS) which has shown that patients meet their goals in most cases.

3.1.2. Research Project - BRaNT

Belief Revision Applied to Neurorehabilitation Therapy is a project to develop a cognitive stimulation system to run on a tablet. It aspires to be orientated to daily life activities as the greater the similarity between training and real life, the greater the possibility of transfer of skill improvement in a protected environment to the real world. The artificial intelligence modules generate a computerized neuropsychological profile based on the initial neuropsychological assessment, which adapts to the patient's performance between sessions. Elements of gamification allow positive feedback. Remote monitoring allows patient performance to be tracked by health professionals, which enables home treatment (Spínola et al., 2021). The system is undergoing randomized control study, and it is planned to be incorporated into the repertoire of cognitive stimulation tools available to the Cognitive Rehabilitation Program.

Figure 2: The four tasks of the BRaNT platform. Adapted from (Paulino et al., 2016)

3.1.3. Research Project - Musiquence

Musisquence is an award-winning platform for customizing music and reminiscence content in cognitive stimulation activities. It was developed using a participatory design methodology and was used to create a seven-week customized cognitive stimulation program (CCSP) for individuals with dementia (IwD). The CCSP was created through focus groups with formal caregivers and by gathering preferences from IwD. The final program consists of seven cycles of tasks that combine activities available on Musiquence with seven preferred themes of IwD and seven songs frequently referenced by formal caregivers (Andrade Ferreira et al., 2019). Musiquence has resulted in the first spinoff company of the NeuroRehabLab. It has not yet transitioned to clinical practice at

SESARAM but it is intended to be subject to further studies and validation for acquired brain injury in the future.

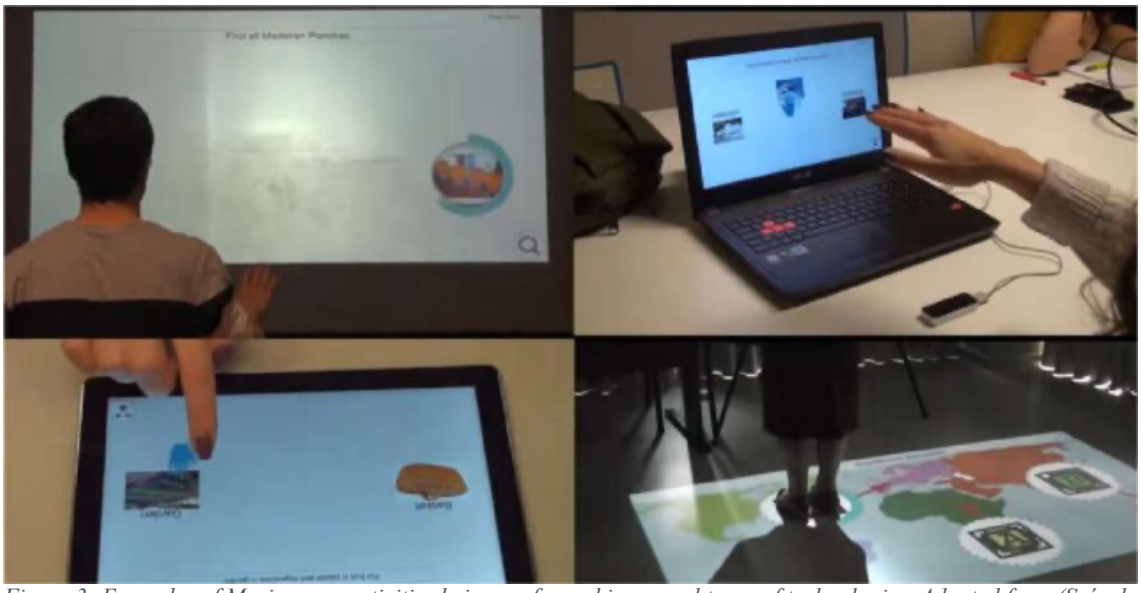

Figure 3: Examples of Musiquence activities being performed in several types of technologies. Adapted from (Spínola et al., 2022)

3.2 Post stroke Motor Rehabilitation

3.2.1. NeuroaugVR

This intervention uses a brain-computer interface driven virtual reality program called NeuRow. The patient is immersed in a virtual world, seated in a canoe, holding oars and hearing the background water. The patient requires the imagination of a rowing motion with upper limbs. Imagination, better known as motor imagery, causes electromagnetic changes on the scalp that can be detected by Electroencephalography (EEG). Feedback is then given back to the patient by visualization of the rowing motion through the virtual reality glasses and vibration of the cylinders placed in the patient's hands. Additional stimuli are provided with cues and reward feedback, such as the capturing of flags (Vourvopoulos et al., 2019).

The purpose of this intervention is to stimulate neuroplasticity(Vourvopoulos et al., 2019). By imaging a movement, areas of the brain can be activated similarly as if the actual movement was being performed. We study the effect of the intervention using clinical scales, EEG analysis and functional MRI.

To date, we have completed a successful pilot study as well as designed and tested different prototypes.

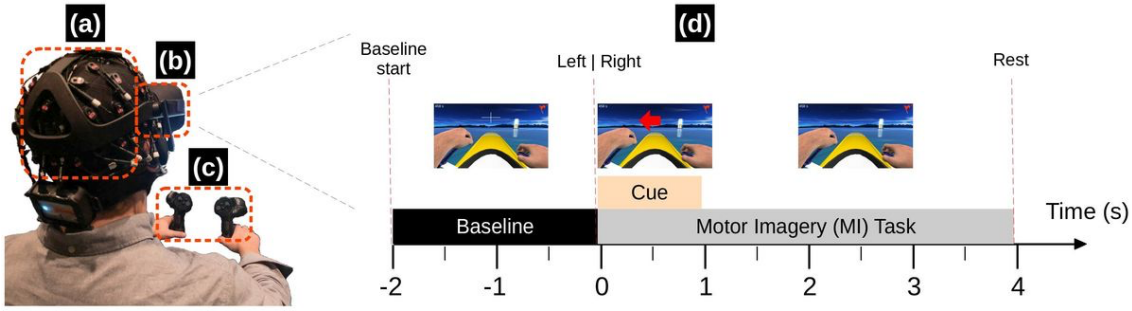

Figure 4: Experimental setup example. (a) 32 active electrodes EEG system; (b) HMD VR; (c) controllers for vibro-tactile feedback, including custom support; (d) MI trial of the training protocol. Adapted from (Vourvopoulos et al., 2022)

3.2.2. Eyeplay

This system was developed by the University of La Laguna. This system uses an eye-tracking system to control a virtual object (Modroño et al., 2020). The use of this design looks to simulate the integrated neural connections between the eye and hand, such as when one controls the cursor on a computer. Lifetech and ARDITI seek to work with University of La Laguna to improve the virtual reality component and assess the clinical benefit of applying this type of system in the early phases of stroke.

3.2.3. Interactive table

This project seeks to examine the impact of different game modes on engagement and social involvement in a two-player game for upper limb rehabilitation through interaction with physical objects. A multi-player setup using tangible objects and an interactive table was developed, and a game was implemented with the ability to switch between competitive, co-active, and collaborative modes (Pereira et al., 2019). The system designed by NeuroRehabLab is a tool that could be used in occupational therapy.

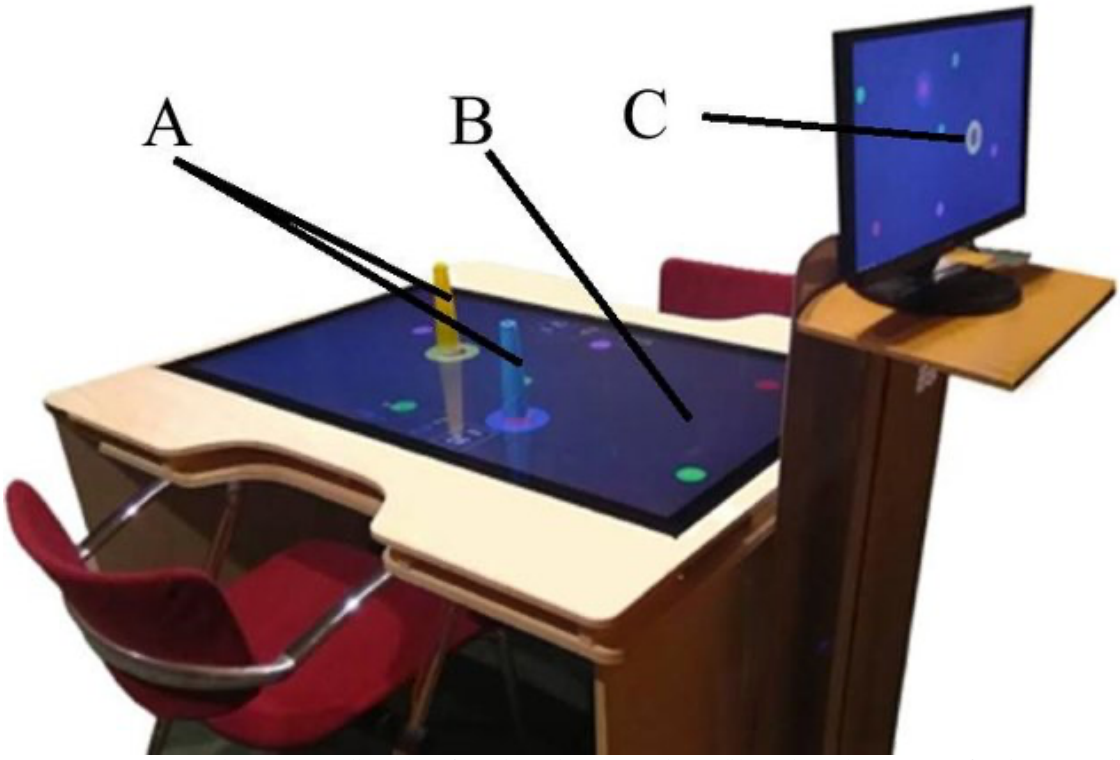

Figure 5:Experimental Setup: Handles (a), infrared touch sensitive layer (b), and auxiliary screen for the researcher (c). Adapted from (Pereira et al., 2021)

3.3 Cardiorespiratory Rehabilitation

The Augmented Human Assistant project offers a combination of ICT and Robotics solutions to promote healthy lifestyles in older adults. The goal is to either prevent sedentary behavior in elderly care institutions or to assist with rehabilitation of motor deficits (e.g. stroke survivors). The project utilizes social assistive robots, interactive feedback, and gamification techniques to keep users engaged in their exercises and motivated through coaching, scores, levels, achievements, and competition with peers. The Portable Exergame Platform for Elderly (PEPE) was designed as part of the Augmented Human Assistant (AHA) project in partnership with the *Instituto Superior Técnico* (IST) to promote exercise in the elderly(Gouveia et al., 2019). We are now studying the feasibility of using this system as an alternative to conventional aerobic exercise modalities such as treadmills and static bicycles for cardiac and respiratory rehabilitation.

Figure 6: PEPE platform being used during a training session.

3.4 Obstetrics/Psychology

Adaptive Virtual Reality for coping with involuntary early pregnancy loss (AViR) is an FCT-financed project that seeks to provide a support tool for grief after miscarriage. The AViR project involves the development of a multi-scenario VR prototype to give personalized support through psychological support protocols to create a tailored experience for each user. The VR prototype will feature procedural generation, non-conversational empathic avatars, and interactive narratives. The virtual scenarios will be implemented in a Virtual Reality Head-Mounted Display to increase immersion and create a safe space for patients to express their emotions freely.

3.5 Pain Medicine

Reliph was a project to provide an alternative to mirror therapy in the treatment of phantom pain of the lower limb. This was a Master's thesis in Interactive Media Design. The prototype proposes a new technological approach based on mirror therapy principles to reduce phantom pain in amputated individuals. The procedure involves creating a virtual reality environment that captures muscle activity in real-time and is controlled by a device. The virtual environment features a game based on simple, effortless exercises without the need for strength. The approach has been tested on healthy subjects and in a case study, with high results in reducing phantom pain, increasing motivation and sense of presence and focus during use

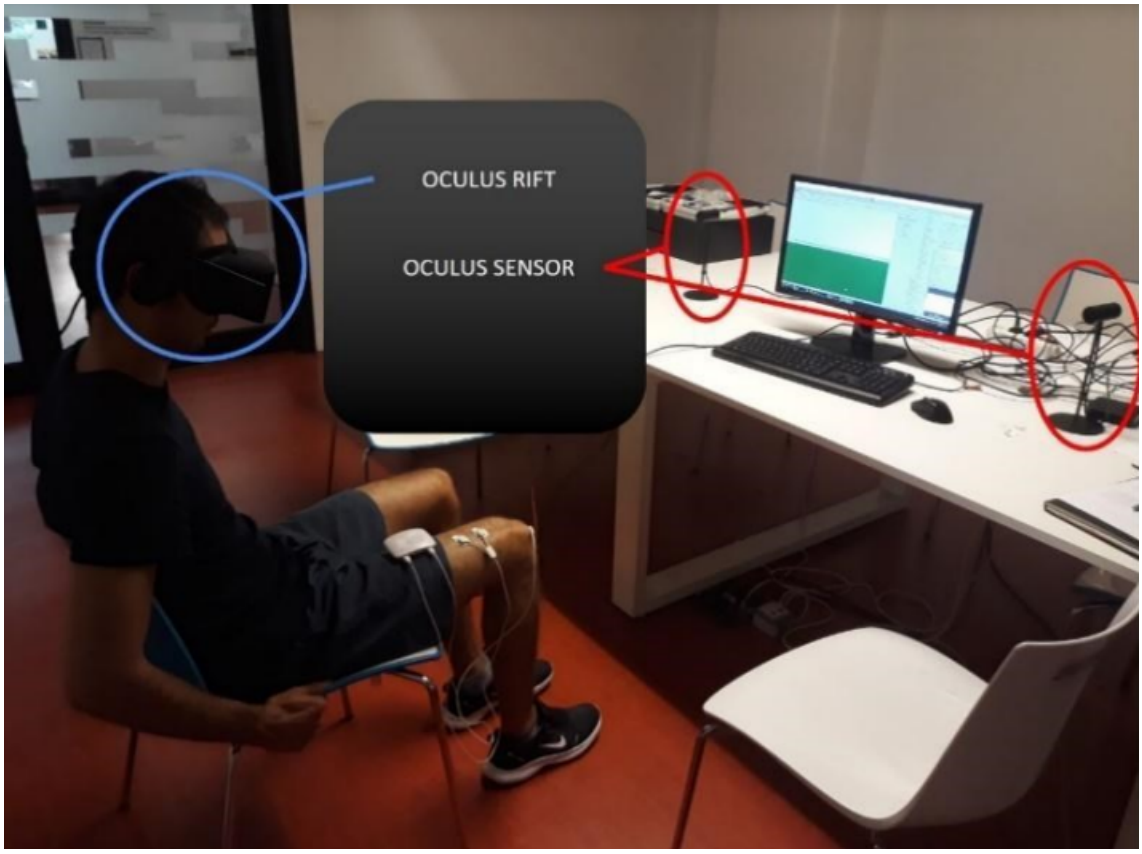

Figure 7: Set up of RELIPH project. Adapted from (Freitas Costa, 2019)

4. Discussion

Lifetech model departs from the traditional separation of hospitals and universities and instead focuses on practical and useful research that can deliver short-term benefits. The model is significant as it comes at a time when the region is in the process of building a university hospital.

The Center focuses mainly on neurorehabilitation but is expanding into other areas such as cardiac and respiratory rehabilitation and non-physical medicine related areas like the AViR project. The cognitive rehabilitation program, which stems from the Lifetech collaboration, has already helped patients with acquired brain injury. However, most of the technology developed by Lifetech is yet to be integrated into routine clinical practice. The Center's research in areas like virtual reality immersion and motor imagery exercises, which are not commonly used, has the potential to optimize current rehabilitation strategies.

In summary, the Lifetech Center serves as a hub for health professionals to come together, share ideas, and collaborate on projects that can improve patient outcomes. The Center provides an opportunity for health professionals, including doctors, nurses, psychologists, and therapists, to expand their knowledge and experience in their respective fields. By being involved in the development of new and innovative technologies, health professionals can play a key role in shaping the future of patient care. The Center also provides education and training in research methodology, giving health professionals the skills and experience needed to design and carry out effective and impactful studies. Overall, Lifetech offers a dynamic and supportive environment that empowers health

professionals to make a positive impact in their field, while also motivating them to break away from routine and explore new and exciting opportunities.

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