Cognitive and Gait Cycle Evaluation with Rehabilitation in Veterans Affected by Combat Causalities and Trauma Using Prosthetics and Artificial Intelligence

Ravindrakumar Selvaraj[1*] and Karthika Priya Rajaram[2]

[1]Professor, Biomedical Engineering, KIT- Kalaignarkarunanidhi Institute of Technology, Coimbatore, Tamil Nadu, India
[2]Assistant Professor/BT, KIT- Kalaignarkarunanidhi Institute of Technology, Coimbatore, Tamil Nadu, India

Abstract

Context: *In war field, the causalities and trauma occurred modifies the gait cycle and causes problems in cognitive functions. The injury may cause critical problems like Altered mental status, Fever, Increased heart rate, generalized edema, The cognitive behaviors will drastically change in the person, the causes may be traumatic brain injury or other brain disorders. The physical deformity of the skull or cranial can create cognitive problems among the veterans.*

Objective: *In this work a design of an equipment for cognitive skills determination using EEG signal analysis is made. The rehabilitation of cognitive skills is to be done by Augmentation and virtual reality based Cognitive-behavioral therapy or CBT system.*

Methods: *The work is to recognize and analysis the human gait from different approaches: image processing, floor sensors and sensors placed on the body. In method 1 , Analog or digital cameras are to be used along with lazer range scanners (LRS), infrared sensors and Time-of-Flight (ToF) cameras. In method 2 wearable sensors located on several parts of the body, such as feet, knees, thighs or waist is used for gait analysis. The walking deviation can be studied by the gait analysis protocol through Biomechanical 3D modelling using Image Processing. gait analysis protocol analyses the pelvis, hip, knee, foot & ankle motion during the entire gait cycle using Tread Mill test. For functional and physical deformity exoskeleton, prosthetics and orthotics design and development is to be done. For functional electrical stimulation, designs combining Embedded, Nanoelectronics and circuits were done. Implants and orthotics devices were designed for the partial support or organs which have functional problems. Software is to be developed for data handling, radiology scan analysis, storage and do all analysis. Artificial intelligence is to be applied for analysis of images like MRI, CT and Xray.*

*Corresponding author: Ravindrakumar Selvaraj, Professor, Biomedical Engineering, KIT- Kalaignarkarunanidhi Institute of Technology, Coimbatore, Tamil Nadu, India.

Introduction

Prostheses, are designed to restore functionality, improve mobility, and enhance the quality of life for veterans is who have lost limbs or other body parts due to injury in battle field. While soft computing methods like virtual and augmented reality recovers the cognitive ability of the patient. Prosthetics have been developed and refined over centuries, with significant advancements in materials, design, and technology. Various materials were used in the process [1-5]. The specific type of prosthetic and its features will vary depending on the level and location of the amputation, the individual's overall health and lifestyle, as well as their personal preferences and goals. The types are Upper Limb Prosthetics and Lower Limb Prosthetics [6-8]. The design focuses on the design on Socket Design, Suspension system and Training and Rehabilitation. Amputees who have undergone a surgical or traumatic removal of a limb, such as an arm, leg, hand, foot, or even a portion of a limb are considered for this paper. The veterans suffer from problems even in due course of time through amputation of limb by trauma, medical illness or surgery, Gangrene-Tissue death caused by lack of blood supply.

In war field, the causalities and trauma occurred modifies the gait cycle and causes problems in cognitive functions. The injury may cause critical problems like Altered mental status, Fever, Increased heart rate, generalized edema, Increased cardiac output and Increased rate of metabolism. The cognitive behaviors will drastically change in the person; the causes may be traumatic brain injury or other brain disorders. The physical deformity of the skull or cranial can create cognitive problems among the veterans. There are loss of arm or leg and the veterans are amputated. The gait cycle of the person gets changed due to the injury in pelvis, hip, knee, foot & ankle motion. Analysis of the human gait guides the way in which orthopaedic developments can be made for veterans.

The cognitive or thinking capability and communication problems can be diagnosed by manual methods. For measuring the internal problems, the scanning methods like X-Ray, Magnetic resonance imaging (MRI), Computed Tomography (CT) and ultrasound imaging. Certain physical and cognitive behavioral changes are observed at latter stages of the causality life. The common difficulties can be treated with regular rehabilitation therapy. Physiotherapy treatments are given for physical deformity. Still new technologies have scope to meet the treatment requirements. In literature gait cycles are investigated through image processing methods. Prosthetics were used for physical deformity.
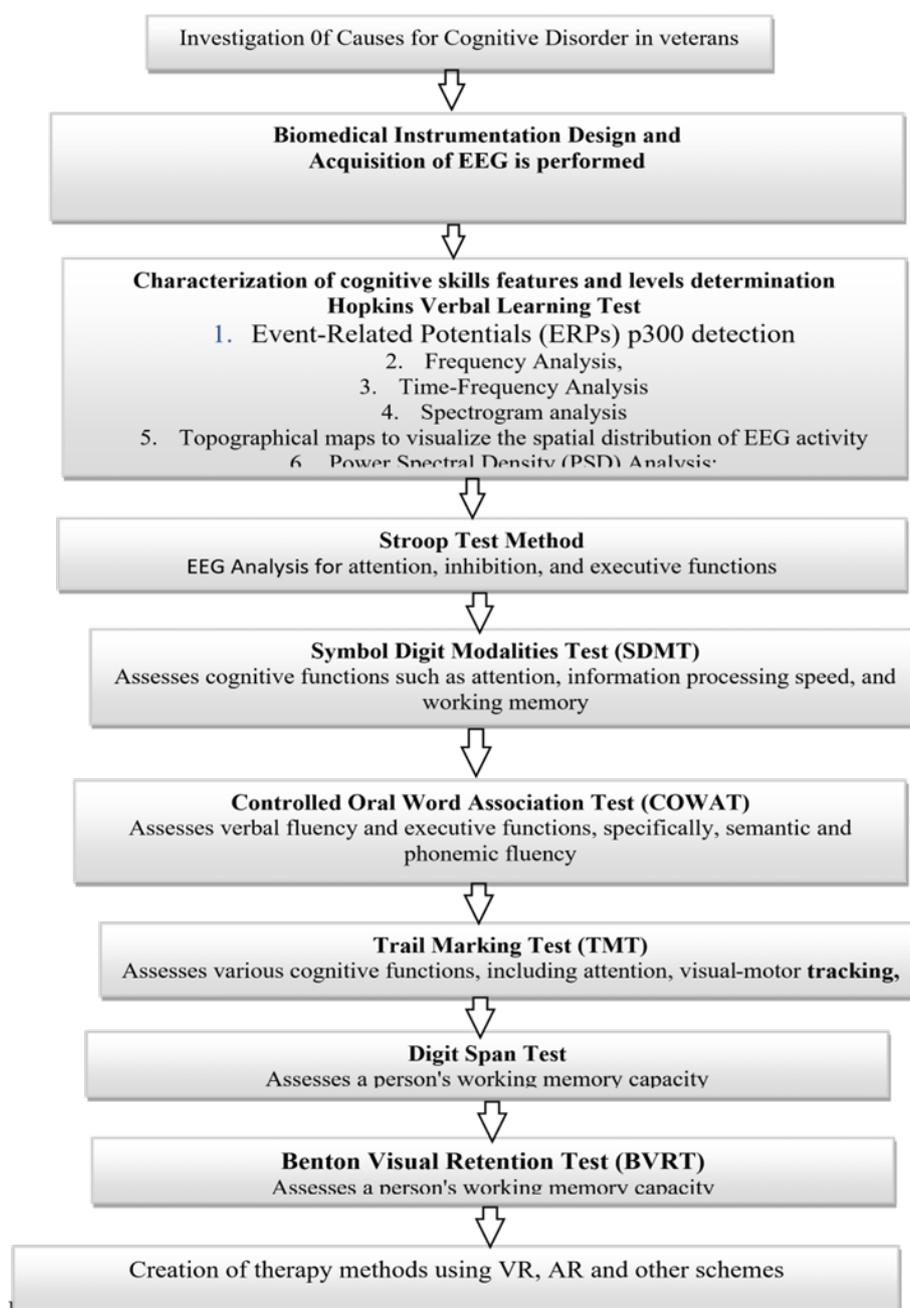
Proposed Method

Gait analysis: The work is to recognize and analysis the human gait from different approaches: image processing, floor sensors and sensors placed on the body. Firstly, an introduction of the key gait parameters and semi-subjective methods is presented. In method 1 , Analog or digital cameras are to be used along with Laser range scanners (LRS), infrared sensors and Time-of-Flight (ToF) cameras. In method 2 wearable sensors located on several parts of the body, such as feet, knees, thighs or waist is used for gait analysis. For this Accelerometer, Gyroscope, and Magnetoresistive Sensors are to be used. the physical deformity problems on left & right extremity posture, postural deviations, gait cycle deviation and locomotion problems can be evaluated. Using computer vision technology the postures are to be monitored and treated. The walking deviation can be studied by the gait analysis protocol through Biomechanical 3D modelling using Image Processing. gait analysis protocol analyses the pelvis, hip, knee, foot & ankle motion during the entire gait cycle using Tread Mill test. The kinematic graphs [Signals, Image-EMG] were used for muscle imbalance investigation.

Cognitive Skills Determination: This project proposes an equipment for cognitive skills determination using EEG signal analysis. The rehabilitation of cognitive skills are done by Augmentation and virtual reality based Cognitive-behavioral therapy or CBT system. By this the common difficulties with cognition (or thinking), Cognitive Communication can be corrected. Various tests like Hopkins Verbal Learning (HVLT), Stroop test, Symbol Digit Modalities Test

(SDMT), Controlled Oral Word Association Test (COWAT) and digital scan test are to be done for cognitive behavior analysis.

The cognitive skills are evaluated using the following steps. Table 1 shows the Cognitive Skills evaluation in veterans affected by combat causalities and trauma.

For functional and physical deformity exoskeleton, prosthetics and orthotics design and development is to be done. For functional electrical stimulation, designs combining Embedded, Nanoelectronics and circuits were done. The investigation on the different types of war amputation shows that there is wide range of product design requirement towards orthotics and prosthetics. The rehabilitation for the amputated patients is done by various prosthetics of upper and lower limb Prosthetic/ Assistive devices. Biomedical signals like EMG and EEG are analyzed to estimate the status of the limb or leg. In few cases before the prosthetic fixing bone mineral density were studied. Implants and orthotics devices were designed for the partial support or organs which have functional problems.

Investigation 0f Causes for Cognitive Disorder in veterans

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Biomedical Instrumentation Design and Acquisition of EEG is performed

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Characterization of cognitive skills features and levels determination Hopkins Verbal Learning Test
1. Event-Related Potentials (ERPs) p300 detection
2. Frequency Analysis,
3. Time-Frequency Analysis
4. Spectrogram analysis
5. Topographical maps to visualize the spatial distribution of EEG activity
6. Power Spectral Density (PSD) Analysis;

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Stroop Test Method
EEG Analysis for attention, inhibition, and executive functions

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Symbol Digit Modalities Test (SDMT)
Assesses cognitive functions such as attention, information processing speed, and working memory

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Controlled Oral Word Association Test (COWAT)
Assesses verbal fluency and executive functions, specifically, semantic and phonemic fluency

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Trail Marking Test (TMT)
Assesses various cognitive functions, including attention, visual-motor **tracking,**

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Digit Span Test
Assesses a person's working memory capacity

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Benton Visual Retention Test (BVRT)
Assesses a person's working memory capacity

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Creation of therapy methods using VR, AR and other schemes

Figure 1. Cognitive Skills evaluation in veterans affected by combat causalities and trauma

Software development: Software is to be developed for data handling, radiology scan analysis, storage and do all analysis. Artificial intelligence is to be applied for analysis of images like MRI, CT and Xray. The MIMICS software is to be used for the prosthetic development. MRI can be used to estimate the muscle and bone characteristics of the residual organ. The Embedded and IoT provides a continuous monitoring and control of wearable devices when the veteran is in observation due to locomotion or complete failure of gait patterns or heavily injured.

Summary of methods available, materials used and side effects. [1-5]

Types	Explanation	Material used	Side effects
Lower limb	Replaces by part of lower limb to restore functional purpose of lower limb	Carbon fibre, Titanium, Kevlar, Aluminium, Plastics, EVA, silicon, Urethane, Gel liners	Skin irritation, Pressure sores, Weight, heat retention.
Upper limb	Replaces part of the arm, it can Range from simple cosmetic arm to advanced myoelectric arms, it generates electrical signals by muscles	Carbon fibre, Titanium, Kevlar, Aluminium, Plastics, EVA, silicone, Urethane, Gel liners	Skin irritation, Pressure sores, Weight, heat retention, Sweating and cosmetics issues.
Bionic	Advanced	Carbon fibre, Titanium, silicone, Plastic, myoelectric, Microprocessor, Batteries, Cosmetics Materials.	Mechanical Failures, electrical sensitivity
Feet and Ankles	Replacement involving lower leg	Carbon fibre, Titanium, silicone, Plastic, myoelectric, Microprocessor, Batteries, Rubber	Mechanical Failures, electrical sensitivity
Cosmetic	Natural look	Acrylic resins, Later, foam, plastics films	Pain, Discomfort, Phantom limb sensation

References

1. Xiaoxuan Lu, Zichen Wu, Kehui Xu, Xiaowei Wang, Shuang Wang, et al. (2021) Multifunctional coatings on titanium implant toward promoting osseointegration and preventing infection: Front. Bioeng. Biotechnol 9: 783816.

2. G¨ulben Avsar, Deniz Agirbasli, Mehmet Ali Agirbasli, Oguzhan Gunduz, Ebru Toksoy Oner (2018) Levan based Fibrous Scaffolds Electrospun via Co-axial and Single-Needle Techniques for Tissue Engineering Applications: Carbohydrate Polymers https://doi.org/10.1016/j.carbpol.2018.03.075.

3. Fatemeh Khosravi, Saied Nouri Khorasani, Shahla Khalili, Rasoul Esmaeely Neisiany, Erfan Rezvani Ghomi, et al. (2020). Development of a Highly Proliferated Bilayer Coating on 316L Stainless Steel Implants: Polymers 12: 1022.

4. Zhenyu Zhong, Jinli Qin, Jun Ma (2015) Cellulose acetate/hydroxyapatite/chitosan coatings for improved corrosion resistance and bioactivity: Materials Science and Engineering C 49: 251-255.

5. Tina Maver, Tinkara Mastnak, Mihela Miheli, Uroš Maver, Matjaž Finšgar (2021) Clindamycin-Based 3D-Printed and Electrospun Coatings for Treatment of Implant-Related Infections: Materials 14: 1464.

6. Catherine GY Ngan, Rob MI Kapsa, Peter FM (2019) Choong. Strategies for neural control of prosthetic limbs: from electrode interfacing to 3D printing: Materials 12: 1927.

7. RS, HM, BR, KK, SB (2025) Development of Control Unit for Ankle-Foot Orthosis. 2025 3rd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT), Bengaluru, India 1046-1051,

8. Justin. Design And Optimization of a Multiaxial Knee Exoskeleton for Lower Limb Rehabilitation. BioMed Bots Assurance Securing Robotics, Healthcare, and IT Convergence, CRC press.