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# BRAIN4TRAIN PROJECT AS AN EDUCATIONAL RESPONSE TO THE CHALLENGES OF POST-STROKE REHABILITATION

## Abstract:

Considering the negative consequences of stroke disease that dramatically reduce the quality of life of post-stroke patients and their families, it is urgent to offer more effective methods and tools for recovering the survivors in a possible short time. They must be accomplished in a way that preserves dignity and motivates the patient to relearn basic skills that the stroke disease may have impaired like bathing, eating, dressing and walking, shopping, speaking, reading and eventually return to working life.

Taking this as a background for consideration, the aim of this paper is to present the research outcomes on the usefulness of the new and innovative rehabilitation pathways basing on Virtual Reality (VR) technologies. Basically, the case studies performed in the rehabilitation centre Technomex from Poland, encompassing the whole stroke patients' rehabilitation procedures with the use of VR were described. Simultaneously, these examples were the base for creating a comprehensive and professional training tool intended mostly for rehabilitators and physiotherapists about using VR technologies in supporting stroke survivors' recovery that is the main objective of the international project titled "Development of Innovative Training Contents Based on the Applicability of Virtual Reality in the Field of Stroke Rehabilitation", Brain4Train (contract number 2017-1-PL01-KA202-038370).

## Keywords:

virtual reality, post-stroke rehabilitation, Erasmus plus project

**JEL Classification:** I00

## Introduction

Stroke disease affects different and important aspect of human activities, functionality, social and daily life. This is because of functional impairments that touch people after stroke located in both motor and cognitive functions. In consequence this can make post-stroke patients dysfunctional in performing instrumental activities of daily living (IADL) especially requiring interactions with the environment and basing on manipulation of objects (e.g. shopping, operating telephone, wearing etc.). Moreover, cognitive impairment leads to post-stroke dementia including vascular dementia, degenerative dementia (VaD), particularly Alzheimer's disease (AD), or mixed dementia (VaD plus AD).

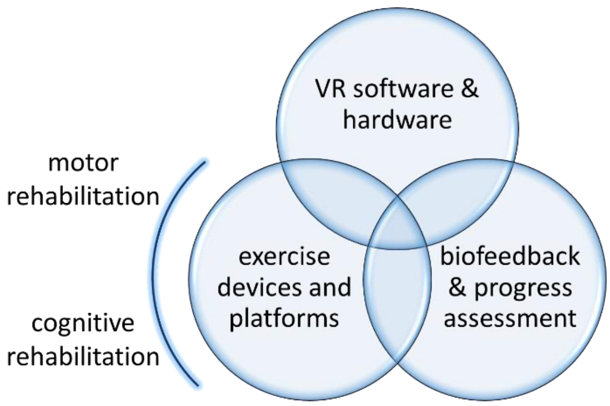
Considering all these negative consequences of stroke, dramatically reducing the quality of life for post-stroke patients and their families, it is urgent to offer effective methods and tools for recovering the survivors in order to make them as independent as possible and in possible short time. These must be accomplished in a way that preserves dignity and motivates the patient to relearn basic skills that the stroke disease may have impaired like bathing, eating, dressing and walking, shopping, speaking, reading and eventually return to working life.

VR technology creates a new opportunity to meet these needs due to:

- the possibility of both effective rehabilitation under clinical control and self-rehabilitation at home that is safe and efficient,
- easy and intuitive to use,
- adaptation to most kind of impairments,
- adaptation to individual interests,
- quick change of the arrangement and conditions of exercise,
- the possibility of achieving milestones, exercises based on competition – prizes,
- adjustment of the exercises to the temperament and personality of the patient etc.

Additionally the basic usefulness of VR technology in rehabilitation is the combination of three groups of integrated components, like in the Fig. 1.

**Figure 1. The components of VR based stroke rehabilitation method**




*Source: own elaboration*

Taking the above considerations as a background for the work on rehabilitation improvement, the aim of this paper is to present the research outcomes on the new and innovative rehabilitation pathways basing on VR technologies giving in the same time an educational content for both medics who are responsible for stroke recovery and for patients and their families who should be aware about new possibilities that can improve their quality of life. Basically, the case studies were performed in the rehabilitation centre Technomex from

Poland, encompassing the whole stroke patients' rehabilitation procedures. Simultaneously, these examples were the base for creating a comprehensive and professional training tool intended mostly for rehabilitators and physiotherapists about using VR technologies in supporting stroke survivals' recovery that is the main objective of international project titled "Development of Innovative Training Contents Based on the Applicability of Virtual Reality in the Field of Stroke Rehabilitation", Brain4Train (contract number 2017-1-PL01-KA202-038370).

## Assumptions for VR based stroke rehabilitation

Two main assumptions were established when recognizing new approach to rehabilitation of post-stroke patients with the use of VR technologies as the key supporting mechanism. They are:

1) integration of motor and cognitive rehabilitation;
2) biofeedback as a motivation tool.

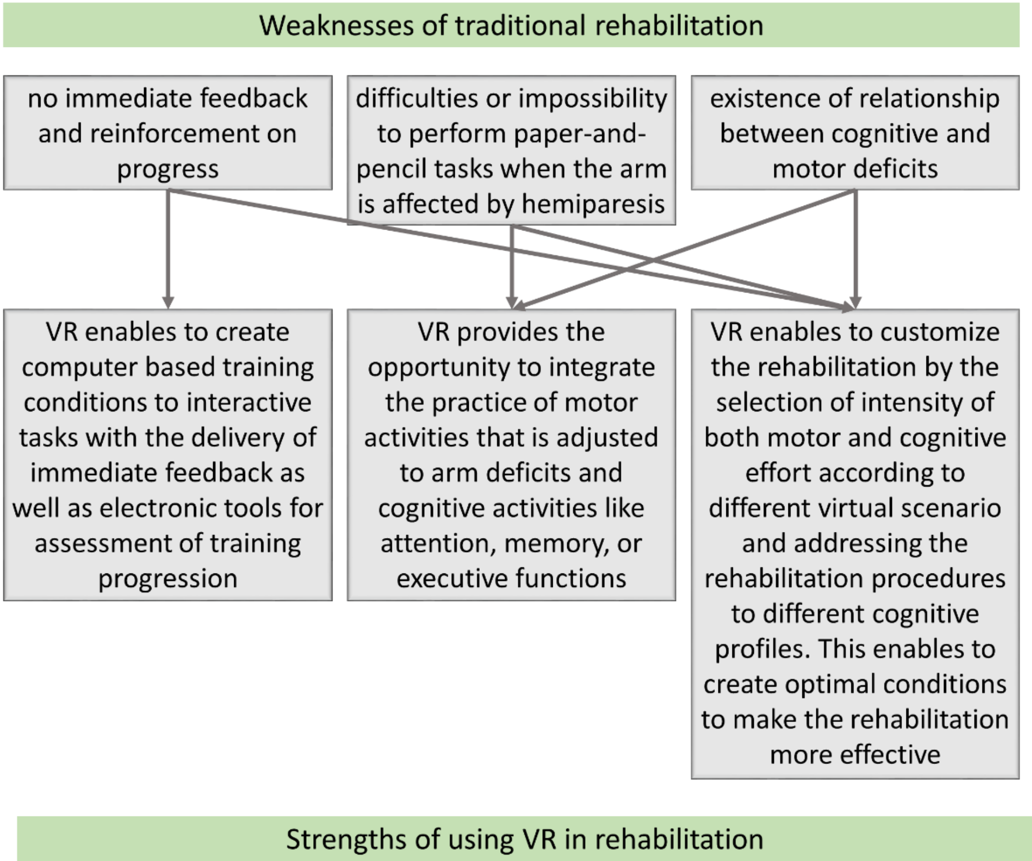
Ad. 1 Integration of motor and cognitive rehabilitation

Normally, stroke rehabilitation methodologies base on improvement of motor skills, although 70% of patients experience some degree of cognitive decline (Gottesman, Hillis 2010). Meanwhile, there are evidences that cognitive deficits interfere with motor recovery (Mullick et al. 2015). Even when cognitive rehabilitation is a part of patient recovery, the traditional approach to treatment methodologies is based on simple tasks with the use of paper-and-pencil tasks (Faria et al. 2018). There are different weak points of this approach to cognitive rehabilitation including:

- no immediate feedback and reinforcement on progress;
- difficulties or impossibility to perform paper-and-pencil tasks when the arm is affected by hemiparesis;
- existence of relationship between cognitive and motor deficits meaning that cognitive training contributes a motor recovery (Verstraeten 2016).

Virtual Reality environment creates the possibility to combine both cognitive and motor rehabilitation that overcome the above mentioned weak points. The reasons for this are presented in the Fig. 2.

**Figure 2. The ways of supporting rehabilitation by VR technology**




*Source: own elaboration*

Ad. 2. Biofeedback as a motivation tool

Biofeedback is a technique that uses electronic apparatus which allows a patient to learn how to change the physiological functions of the body to achieve improvement of health as well as efficiency and effectiveness of a specified body functions. Biofeedback is also identified as a body-mind training method that helps patients to achieve their awareness and to control their physiological processes such as: breathing, heart rate, muscular tension, skin temperature, an electro-dermal reaction, blood pressure or hemoencephalographic record (Kwolek at al. 2013). Together with development of VR based therapy of stroke patients, the new solutions for providing biofeedback were emerged. This new approach to the biofeedback is based on presentation of information to patient in visual and intuitive way. Such an intuitive form of feedback is more easily perceived by brain injured patients than multiple abstract and quantified presentations that use formulas or numerics (Huang et al. 2006).

VR based biofeedback systems sustained attention, self-confidence, and motivation of participants when performing repetitive tasks thanks to multimodal displays and interactive trainings. In many cases, the training scenarios are designed as games, such as goal keeping or tennis playing as well as other games requiring execution of subsequent tasks, in an effort to engage the patient's active participation (Huang et al. 2006). That is why this approach to biofeedback is referred to “task-oriented biofeedback” or “dynamic biofeedback”. This approach highlights the interactions between the neuromuscular system and the environment that exist in real life. VR technologies give the possibility for reflecting this interactions by incorporating movement components into an artificial environment that resemble the given task in the relevant functional context. It is important that task must be linked to a clearly defined functional goal. In neuromotor rehabilitation, task-oriented training encourages a patient to explore the environment and to solve specific movement problems (Wann, Turnbull, 1993).

VR based biofeedback support rehabilitation of post-stroke patient in effective way because (Huang et al. 2006):

- is multimodal, so perceptive and cognitive functions are involved in the physical therapy;
- is attractive and motivating, to keep the subject attentive;
- is easy-to-understand, to avoid the information overloading problem. Multimedia uses computerized graphics/animation, sound, and/or haptic stimulation to immerse the user in a constructed virtual environment;
- it can be used anytime and anywhere also at home enabling telerehabilitation thanks to information and communication technologies (ICT) like wireless Internet that allow to connect with therapist in both online or offline way.

## Virtual Reality in stroke rehabilitation – case studies

### Description of case studies

There were performed two types of case studies. The first type describes a simulation with participation of health person that used given VR devices normally supporting stroke rehabilitation. The assumption was formulated that the health person use the VR devices for the first time and assess the first impression. The aim of such simulation was to verify the difficulty level taking into account three aspects:

1) motor tasks;
2) cognitive tasks;
3) the commends provided by physiotherapist of how to perform the tasks.

The method for assessing the difficulty level was 7 point Likert scale that was base for developing evaluation questionnaire, see the Fig. 3.

**Figure 3. The evaluation questionnaire for assessing the motor and cognitive functionalities of VR devices**

**I understand the task**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

**I know how to do the task**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

**It is simple to use**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

**It is user friendly**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

**It is fun to use**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

**Motor tasks are simple – I do not have problems with achiving tasks objectives**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

**Cognitive tasks are simple – I do not have problems with achiving tasks objectives**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

**Biofeedback motivates me**

Strongly Disagree ---1---2---3---4---5---6---7--- Strongly Agree

*Source: own elaboration*

The second type describes a case study with participation of a patient after stroke giving the results of the whole rehabilitation process.

The case studies were performed in rehabilitation centre of Technomex (Poland) that provide health services for patients after stroke basing on VR devices. Each of them includes treatment and assessment procedures with biofeedback.

Within two cases different devices were used. The Table 1 presents a specification of case studies including type of device and its functionalities.

**Table 1. Devices used within case studies**

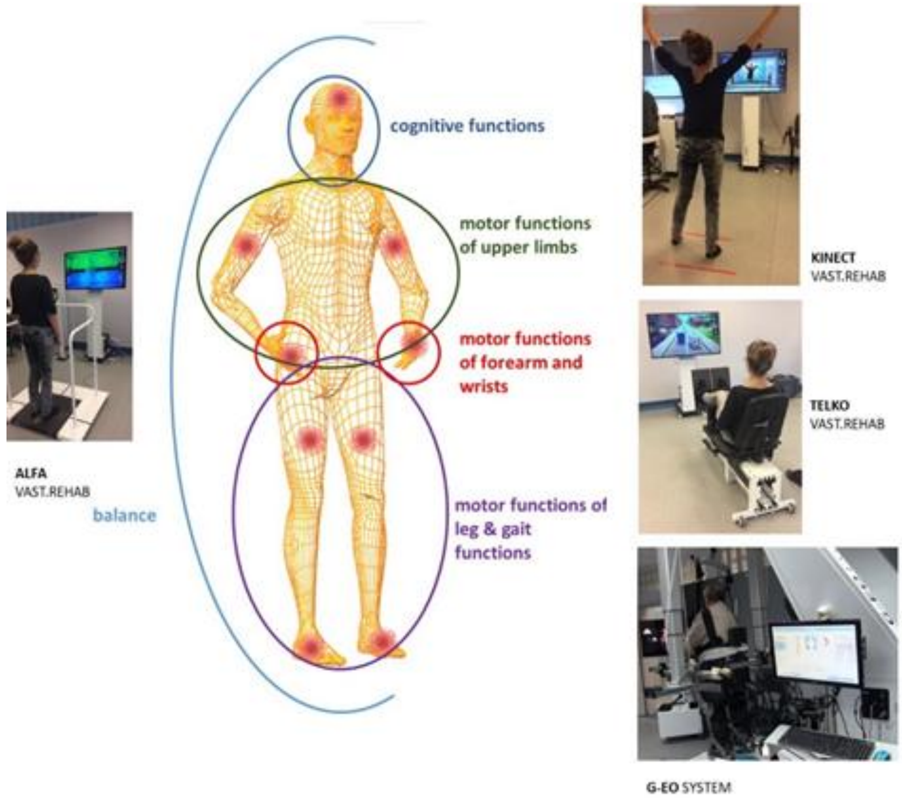
| Type of device | Type of Functions | | | | | Type of case study |
|---|---|---|---|---|---|---|
| | cognitive functions | motor functions of upper limbs | motor functions of forearm and wrists | motor functions of leg & gait functions | balance | |
| **KINECT** | **x** | **x** | **x** | **x** | **x** | case study 1 |
| **TELKO** | x | | | **x** | | case study 1 |
| **G-EO** | | | | **x** | | case study 2 |
| **ALFA** | x | | | **x** | **x** | case study 1 |

*Source: own elaboration*

Particularly in the table the main supporting function or functions were marked (**x**), however it is important to know that all these devices, even if dedicated mainly to support motor functions, simultaneously recover cognitive impairments in a specified range (x).

Figure 4 presents pictures when using each kind of above mentioned device.

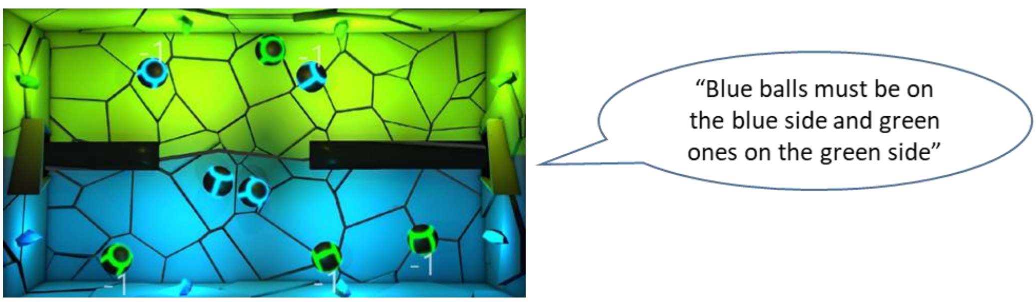
**Figure 4. A combination of different VR solutions for stroke rehabilitation used in case studies**




*Source: own elaboration*

The ALFA is a stabilometric platform (on a stable foundation) that allows both balance assessment and balance training of neurological and orthopaedic patients. Particularly this device helps to increase the efficiency of patients functionality after strokes, head injuries, as well as those suffering from multiple sclerosis, Parkinson's disease and having muscle dysfunctions. In addition, it accelerates recovery after fractures and sprains of the ankle joint, knee joint and dislocation of the hip joint. Alpha also enables the therapy of patients after amputations of the lower limbs. The range of functions trained with the use of Alfa platform are: repetition of movements in 3D space, scheduled movements, strengthening muscle strength, precision of movements, visual and motor coordination, balance, rhythmics, activity at a given rhythm, raising hands, concentration, perceptivity, planning and strategy, speed of decision making. In the Fig. 5 there is presented an example of VR game with instructions about particular task.

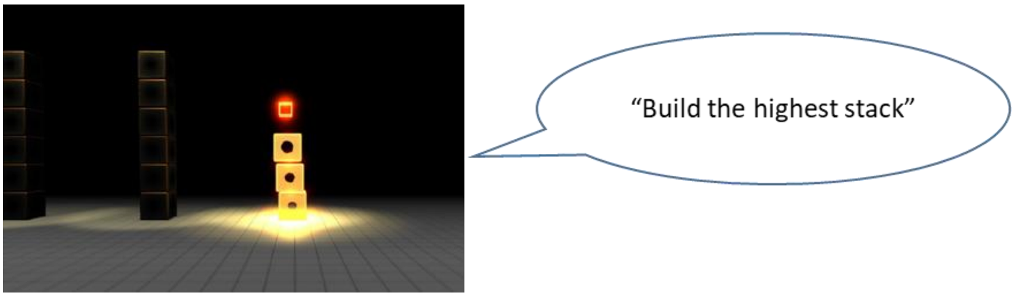
**Figure 5. The example of screen with virtual task integrated to ALFA platform**




*Source: own elaboration*

TELKO is used in comprehensive rehabilitation of lower limbs in a closed kinematic chain. It uses elastic resistance, that generate light resistance in the initial phase of movement, evenly increasing in the later stages of the exercise. The device also uses an integrated two-plate dynamographic platform that extends training opportunities for balance and coordination exercises. TELKO is particularly useful in post-traumatic, post-operative, orthopaedic and neurological rehabilitation. It is also used in sports rehabilitation, rheumatology and geriatrics.
The main functionalities of this system are: repetition of movements in 3D space, scheduled movements, strengthening muscle strength, precision of movements, visual and motor coordination, balance, rhythmics, activity at a given rhythm, raising hands, concentration, perceptivity, planning and strategy, speed of decision making. In the Fig. 6 the example of game exercising balance is presented.

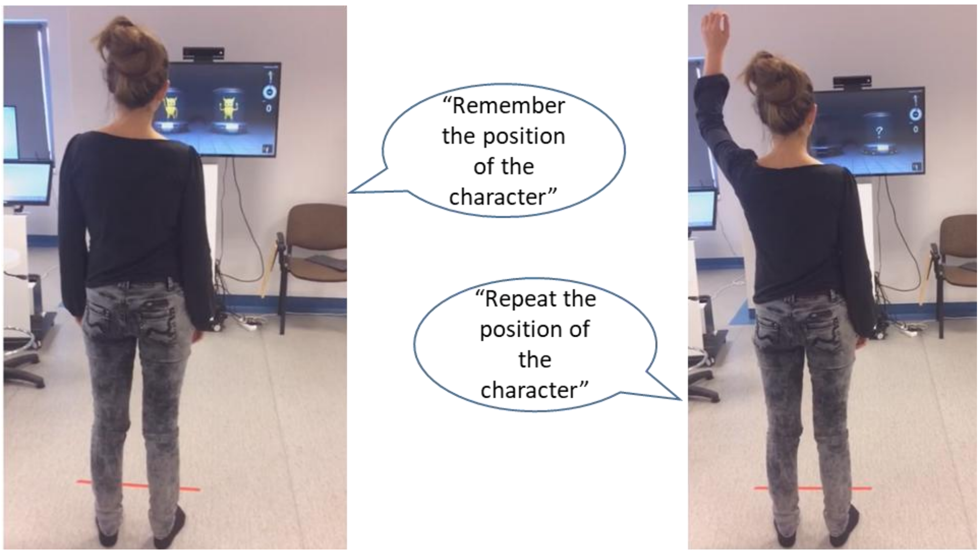
**Figure 6. The example of screen with virtual task integrated to TELKO platform**




*Source: own elaboration*

KINECT allows to work with patients in specific ranges of motion, engaging selected body segments, in many starting positions and using additional devices. Due to these properties, KINECT can be helpful in post-traumatic, post-operative, orthopaedic and neurological rehabilitation in both children and adults. KINECT is also used in rheumatic and geriatric rehabilitation. The main functionalities of KINECT are following: static and dynamic movements, balance training, measurement of angles, speed and acceleration, a wide range of analysed data, ready-made exercise templates and the ability to create your own, objectification of the rehabilitation process, adjusting the level of difficulty, exercises for the current needs of patients. In the Fig. 7 an exercise with the use of KINECT system is presented.

**Figure 7. The example of using KINECT to exercise memory and motor functions**

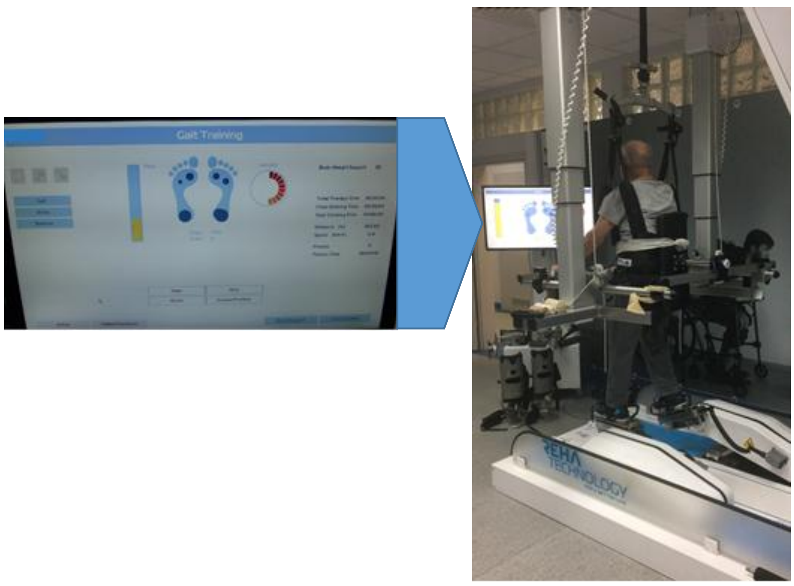



*Source: own elaboration*

The G-EO System® is a robot for the rehabilitation of gait in patients with movement disorders of the lower limbs, e.g. patients after stroke. It consists of electrically powered mechanisms (double sledge for feet), a support frame with a patient harness, a control and control panel, and an operating unit in the form of a PC. The treatment encompasses learning to walk including three different trajectories for: (a) stair climbing up, (b) floor walking, (c) stair climbing down.

In the Fig. 8 a case of exercising by stroke patient with the use of G-EO system is presented.

**Figure 8. The example of using G-EO System® to exercise motor functions with biofeedback graphical representation**



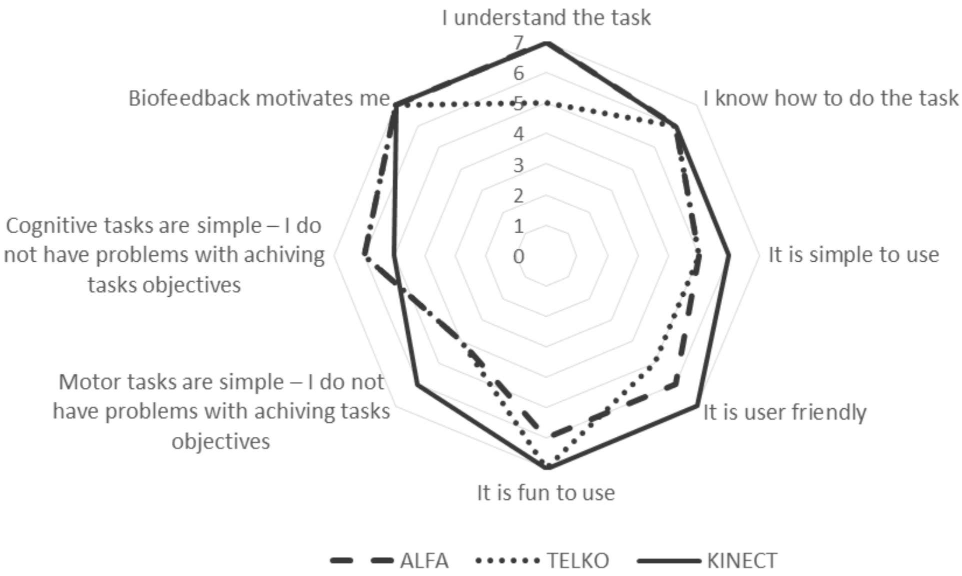
*Source: own elaboration*

## Results

### Case study 1

Several tasks for each device were conducted within the case study 1 by a volunteer. The overall evaluation of their functionlities is illustrated in the Fig. 9.

**Figure 9. The results of evaluation the motor and cognitive functionalities of VR devices**




*Source: own elaboration*

The best results was obtained for Kinect system. This system is the simplest and the most user friendly when comparing with ALFA and TELKO devices. The reason may lie in the lack of the need of using additional equipment, except the screen with VR game. The volunteer reaction on graphically provided tasks were rather intuitive and the tasks description understandable. In all cases the biofeedback was treated as a highly motivated tool that helped in achieving better results and simultaneously encouraged a greater effort. TELKO system was more problematic regarding factor “user friendly” because of sitting position with straight legs and the motor difficulties when it comes to feet movements. Nevertheless, all tested devices brought good or very good score that is the a great prognostic for activities aimed at dissemination of indicated methods as desirable forms of stroke rehabilitation.

**Case study 2**

Below there is described patient’s characteristic:

- Patient's age: 63 years
- Disease information: ischemic stroke in 2015 in the PACI location; Pyramid left-sided paresis of 4 degree, NHSS 5.5
- Walking without help - it is only for short distances with a great fatigue

According to Lovett scale, the health factors were:

- Before therapy: quadriceps 4; sciatic- shin 3; three-headed calf: 3.
- After therapy: quadriceps 4; sciatic- shin 4; three-headed calf: 4.

The rehabilitation procedure included walking on the G-EO system 2 times a week for 45 min. The duration of the whole training was 3 months. In addition, before and after a three-month rehabilitation period, the additional equipment: Zebris treadmill was used to test balance assessment and load assessment of lower limbs (right / left, front / back). The test was done when standing position with eyes open for 30 seconds and with eyes closed for 30 seconds. Zebris system is a comprehensive device for objective assessment and gait training as well as postures with substitute feedback. Treadmill with an integrated sensor matrix creates a measuring surface under the transmission belt of the treadmill. A special algorithm calculates

the gait parameters on the treadmill and gives the opportunity to evaluate its individual phases.
After the therapy, a walking test on the treadmill was additionally performed (assessment of individual gait parameters if the patient's natural gait allows for safe conduct of this test).

## Summarizing

Virtual Reality is not commonly used in clinical rehabilitation yet. This results from a lack of ability of medics to use them insomuch as the new and innovative methods are not available in traditional education. Hence, the widely accessible knowledge about what is VR technologies and how to use it in stroke rehabilitation gives a great opportunity to support patients rehabilitation with stroke disease.
Additionally such systems can be easily customized according to different profiles and preferences of stroke survivors. Particularly it can be done by stimulus selection from emotionally tagged pictures or content personalization to patients' preferences like favourite music. Tasks supported by personalized stimuli can enhanced positively valence because of better motivation to effort.
When designing a rehabilitation process for patients after stroke it is recommended to use various combination of equipment and games implemented because:

- patients are not bored and therefore more motivated to do exercises,
- exercising motor functions (by means of devices focused on this field of rehabilitation) they additionally can improve cognitive functions. It is important to take it into account when selecting VR games in order to strengthen certain cognitive functions in the same time, that affect the patient,
- the rehabilitation will be complex, integrated and comprehensive giving chance to shorter recovery time.

Additionally it is crucial the close cooperation between an interdisciplinary team members including both neurologoptists and physiotherapists and representatives of other medical specialties in the process of creating VR games scenarios. On the other hand physiotherapists should be educated in the field of designing individual programs for patients with the use of these games. Dissemination of knowledge about the nature of post-stroke impairments located in both motor and cognitive fields as well as about tools that integrate motor and cognitive rehabilitation may contribute to reaching out to patients who have not had the opportunity to participate in neurologopedic and neuropsychological rehabilitation, although such a one is needed.

### Acknowledgment

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