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Interactive motion-controlled games in the neurorehabilitation of adult post-stroke patients

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Abstract

Despite efforts of scientists and clinicians stroke still constitutes one of the major causes of disability worldwide. Motion-controlled video games become increasingly common adjunct to the traditional physical therapy. Such games are usually available, low-cost, fun, and functional ways to increase everyday treatment possibilities, both in hospital, ambulatory and home settings. Research and scientific publications concerning this issue are still rare. Assessment how interactive motion-controlled games can be incorporated into current guidelines of the eclectic approach within neurorehabilitation of adult post-stroke survivors is key issue within contemporary neurorehabilitation of adults. Complementary use of such games may constitute another breakthrough both in in-patient and out-patient rehabilitation and care. This review aims at potential of aforementioned solutions and modalities for the rehabilitation of function in cases of stroke.

Introduction

Despite efforts of scientists and clinicians stroke still constitutes one of the major causes of disability worldwide. Motion-controlled video games, such as Nintendo Wii and Xbox Kinect, become increasingly common adjunct to the traditional physical therapy. Such games are usually available, low-cost, fun, and functional ways to increase everyday treatment possibilities, both in hospital, ambulatory and home settings. Games allow for:

- application across different functional levels,
- application despite heterogeneity of the post-stroke population,
- individually shaped variety of activities representing physically and cognitively challenging tasks;
- increased motivation and repetitive practice thanks to engaging nature of games and common use of biofeedback;
- objective monitoring of performance and its changes over time;
- complementary use of biomechanical and kinematic in-game markers (start and end points, path ratios, smoothness of trajectories, velocity peaks), in addition to standard clinical outcome (Functional Independence Measure, Fugl-Meyer Scale, Trunk Impairment Scale, Wolf Motor Function Test, Postural Assessment Scale for Stroke, etc.).

Limitations are also important:

- few games dedicated to rehabilitation, especially neurorehabilitation of post-stroke patients,
- challenging games may be too dificult for patients with deficits – aforementioned solutions need for continuous adaptation of tasks and their parameters (operation of control devices, speed and complexity of changes within scenario);
- need for relatively prolonged concentration and attention may be too demanding in certain patients,
- need for relatively huge amount of repetitive movements may be too demanding in certain patients,
- frustration of patients when games are not easy adjustable or achieved result (feedback, score, etc.) is not satisfactory;
- boredom in patients not challenged enough by the game;
- although there is not expected that all levels of such game will be completed by all patients, any competition between patients is not good solution since usually proper patterns of movement are more important than speed of the movement;
- possible increase in pain, fatigue, and exertion after the game-based sessions.

The another problem is psychological: if patients feel better if they think that play succesfully the same games as healthy people (Nintendo Wii, Xbox Kinect, etc.). Feeling of being as dexterous as healhy people may be more motivating for some patients. Unfortunately current recovery is limited, and health-related quality of life in stroke survivors can change their functional and cognitive abilities, independence and life attitude.

Novel technical solutions are rather well accepted by patients and their families, but need for careful application, assist, and training in the elderly patients where digital gap may be more visible.

Despite motion-controlled video games are common used in the neurorehabilitation, research and scientific publications concerning this issue are still rare. Assessment how interactive motion-controlled games can be incorporated into current guidelines of the eclectic approach within neurorehabilitation of adult post-stroke survivors is key issue within

contemporary neurorehabiltation of adults. Complementary use of such games may constitute another breakthrough bot in in-patient and out-patient rehabilitation and care. This review aims at potential of aforementioned solutions and modalities for the rehabilitation of function in cases of stroke.

Games in the therapy of post-stroke patients

Game-based training in patients after stroke demonstrated efficacy, acceptability and safety. There are evidences for statistically significant improvement in upper limb function and balance [1, 2, 3, 4, 5, 6, 7]. Studies in other neurological populations may also constitute preliminary findings for development similar solutions in post-stroke patients [8, 9]. Choice of type of exercsies and optimal dosage, intensivity and number of repetitions still remains unclear and depend on the patient deficits [1]. Some studies comparing game-based and conventional rehabilitation did not detect change, so further high-quality studies are nedded to demonstrate the efficacy of various theraputic methods, techniques and tools in stroke rehabilitation [10].

Many current systems (Nintendo Wii, Xbox Kinect, etc.) are not specifically designed for rehabilitation purpose. Thus their limitations may be significant in post-stroke aptients and influence to therapy outcomes. There is need for important evidence-based discussion on acceptability, safety and efficacy of game-based interventions improving transfer, balance, gait training, upper limb function, and activities of daily living. Associated recommendations for future game-based rehabilitation research, development, and clinical application are necessary [1].

Virtual reality in neurorehabiltation of post-stroke patients

Virtual reality (VR) and interactive video gaming may increase overall therapy time, patient's motivation or adjunct limited dose of conventional therapy. It may provide spontaneous game play with therapeutic system allowing (for patient: in the background) for assessment and rehabilitation. Multifunctionality of VR solutions allow for use them in post-stroke patients with certain cognitive disorders. Even reduced playfulness or boredom with traditional rehabilitation exercises may be treated using virtual reality. Such approach helps achieve the best level of functional skills accessible for a particular patient. We should take into consideration that full independence may be out-of-reach in selected patients, and VR-based user-friendly supporting devices may be constant element of the real environment of such patients, e.g. within smart home control system. Thus transfer from VR-based rehabilitation to VR-based home care should be as smoot as possible.

VR-based systems allow for complementary use of biomechanical and kinematic in-game markers as supplementary to standard clinical outcomes. Such assessment and tracking a patient's outcomes may significantly increase rehabilitation outcomes (Functional Independence Measure, Fugl-Meyer Scale) [11].

Term "VR" cover whole family of solutions (see e.g. taxonomy of mixed reality by Milgram & Kishino). Influence of various solutions to patient may vary depending on many factors. Current evidence is insufficient to assess effectivity of VR influence on patient's functional abilities (global motor function, gait speed, grip strength, etc.). We don't know which features of VR are most important to achieve therapeutic success – it needs further research [12]

Effective rehabilitation require appropriate selection of the applied methods (techniques, tools) and their features (kind of exercises, way of stimulation and motivation, number of repetition, level of the load and support, etc.). In selected case balanced simultaneous

recovery of all handicapped skills (motor, cognitive, social, etc.) can significantly influence both assessment/reassesment procedures and subsequent stages of the therapy to ensure quick and safe recovery. Some selected exercises may be contradictory or incompatible, and there is need knolwedge and experience far beyond machine's artificial intelligence to join them and create patient-tailored approach.

Potential of therapeutic video games in telerehabilitation and integrated systems

Motion-controlled video games might serve as an alternative way of delivering rehabilitation services in situations in which:

- conventional therapy is not readily available [9],
- constitute element of bigger system providing therapy and/or care (e.g. IT environment of disabled person).

Thus motion-controlled video games may play key role within telerehabilitation, including post-stroke. Currently there is still more questions than answers. We know that:

- it should facilitate communication between patient (in remote location) and medical staff,
- increasing speed and development of communication technologies improve effectivity and spread of it.

But there are still discussion (and evidences are insufficient) concerning:

- efficiency of the afrementioned distant model of delivery relative to traditional (face-to-face) rehabilitation,
- relation between intensity of the therapy and rehabilitation outcomes,
- distant intervention approach or even certain exercises providing greater independence, improved mobility, health-related quality of life, upper limb function, cognitive function, and communication skills,
- customizing of patient intervention (toward patient-tailored therapy),
- safety,
- adverse events,
- feasibility,
- patient satisfaction,
- cost-effectiveness [13].

Moreover telerehabilitation has disadvantages concerning data security and privacy, dehumanization of medicine (lack of real interhuman interaction) and accuracy of the distant assessment in neurology/neurorehabilitation.

The most promisig solution is videogame-driven telerehabilitation (VGDT), but feasibility of it is still under research [14]. Intensive continuous post-stroke rehabilitation seems be currently beyond financial possibilities of the public health system, and videogame-driven telerehabilitation at patient's home can be very useful solution of this problem [15].

Discussion and conclusions

Game-based exercises became important adjunct rehabilitation method both in inpatient and outpatient setting. Majority of post-stroke survivors at every stages of recovery should be capable to use such solutions, finding them helpful and enjoyable. Despite quick development of therapeutic low-cost games such solutions suitable for use with people affected by stroke are still rare. Usability, acceptability and safety of aforementioned solutions constitute the most important directions for further research. Assessments for post-stroke patients are widely used despite floor and ceiling effects have been reported [16]. Thus assessments should be made by an experienced therapists. Optimal type, timing, setting and duration of the game-

supported therapy should be established taking into consideration other elements of multidemensional rehabiltiation of post-stroke patient (kinesitherapy, pharmacology, occupational therapy, neurologopedy, etc.).

Main area of described solutions application are walking, standing based activities, trunk control, and balance (weight shifting) exercises, as far as transfers and mobility, and abilities of upper limb (e.g. reaching, grasping). But we should take into consideration that such exercises in artificial controlled environment (e.g. VR-based) should be as close to the real settings as possible. The functional movements should be promoted. The ultimate outcome of the exercise protocol is real improvement in patient's functional abilities reflected in clinical scores and scales. Despite possibility of partial dynamic body weight lifting exercises should provide endurance need for further stages of neurorehabilitation and functional independence. Optimal level of support and challenge may be tailored individually to the patient's need.

One of the most important and challenging group constitute patients with disorders of consciousness (DoCs). Their semi-automatic rehabilitation is still at the beginning of its development, but can provide more accurate patient monitoring, assessment, and higher efficiency. In patient with DoCs motion-controlled games should be partly replaced by simple BCI-controlled or eyetracking-contolled games, but their development is continuous and inevitable.

Motion-controlled video games showed potential as effective and feasible adjunct post-stroke rehabilitation options. Efforts toward new paradigm of game-supported intervention are precious despite achievement of the therapeutic success still constitutes true challenge. Current studies provide information concerning feasibility of the proposed solutions. Development phase of motion-controlled video games may limit not only number of relevant studies, but also many parameters such as activities to choodse or variations within the game. Validation of the game may be also limited by lack of knowledge which scores and scales are the best fitted to the properties of games. It seems whole new methodology and guidelines should be developed in the aforementioned area. Evidence-based medicine (EBM) approach is key approach to reliable evidences and knowledge-based practice. Novelty and quick development of motion-controlled video games technology (see e.g Magic Leap 3D computer-generated imagery over real world objects) causes that current work will never be finished, but still updated. Novel solutions will require novel approaches, studies, and EBM-based guidelines. From the other hand development of novel technologies will be stimulated by clinical requirements and changing profiles and needs of post-stroke patients. Postulated in post-stroke survivors patient-tailored therapy requires more detailed assessment of its efficacy, including compartmental studies between two distinct approaches to the disorder. Application of detailed schemes in this area is difficult or even impossible.

To sum up potential of motion-controlled video games in post-stroke neurorehabilitation seem be still underscored. Due to few studies and weak evidences some commercial devices may pretend to play role of rehabilitation tools. Such risks should be taken into consideration and solved by clinicians, researchers and engineers.

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