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Editorial

EDITORS' LETTER

This volume 4, number 2 is a special issue including a selection of research articles based on papers from 2012 International Conference on Disability, Virtual Reality and Associated Technologies.

This special issue comprises 7 articles, most dealing with rehabilitation or evaluation of patients with brain injury. From those, there is research focused on motor rehabilitation, through games or other methodologies and research on virtual reality for cognitive assessment.

In line with the previous research, it is present in this issue literature review on the telerehabilitation of stroke patients.

Complementing this issue, it is included research on a game for speech training for people with hearing impairment.

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Accessibility Chair Director UPC-BarcelonaTech
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EDITORIAL

ARTICLES

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AGILE DEVELOPMENT OF A VIRTUAL REALITY COGNITIVE ASSESSMENT

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Abstract: In recent years user-centered design, participatory design and agile development have seen much popularity in the field of software development. More specifically, applying these methods to user groups with cognitive and motor disabilities has been the topic of numerous publications. However, neuropsychological assessment and training require special consideration to include therapists and brain-injured patients into the development cycle. Application goals, development tools and communication between all stakeholders are interdependent and outlined in a framework that promotes elements of agile development. The framework is introduced by example of a virtual reality cognitive assessment for patients with traumatic brain injuries. The assessment has seen a total of 20 iterations over the course of nine months including changes in task content, task difficulty, user interaction and data collection. The framework and development of the cognitive assessment are discussed.

Keywords: Virtual Reality, Cognitive Assessment, Agile Development, Neuropsychology

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Introduction

Virtual reality (VR) applications have been successfully applied in a wide range of clinical scenarios (Koenig, 2012; Riva, 2005; Rizzo et al., 2010; Rose, Brooks, & Rizzo, 2005). Their strengths and capabilities have been described numerous times (Rizzo & Kim, 2005; Rizzo, Schultheis, Kerns, & Mateer, 2004). One of the main weaknesses of virtual environments, their immature engineering process (Rizzo & Kim, 2005), has seen much improvement by two recent advances in software development. Continuous innovations in computer technologies and the availability of new software development methods have contributed to VR applications becoming more accessible to researchers and clinicians. Especially the rise of computer games and game engines has spurred a vast growth of the number of development tools available to researchers (Siwek, 2007; Trenholme & Smith, 2008). With such tools the rapid development of virtual environments and clinical tasks can be achieved (Koenig et al. 2011, Koenig, 2012).

Agile software development (Beck et al., 2001; Cohen, Lindvall, & Costa, 2003) and techniques such as participatory design (Astell et al., 2009; Bruno & Muzzupappa, 2010), co-design (Dewsbury et al., 2006; Francis, Balbo & Firth, 2009; Freudenthal, Stüdeli, Lamata & Samset, 2010) and user-centered design (Fidopiastis, Rizzo & Rolland, 2010) have been successfully applied towards the creation of VR and health care applications.

An agile development method can best be established by continuous communication between software developers, clinicians and patients. By iteratively adapting the application requirements to user feedback and needs, the development process remains flexible throughout the application's lifecycle. Working software should be put into the hands of users as early as possible during development while minimizing the time needed to write documentation or make elaborate plans for the software's future iterations (Beck et al., 2001).

In line with agile development, a multitude of design methodologies has been published recently that give the user a central role in the development process. User-centered design places its focus on defining requirements and

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building software that is relevant to the users and their problems. For example, Gabbard, Hix and Swan II (1999) distinguish a behavioral and constructional domain when developing virtual environments. User interaction and the user's view of the developed system are represented by the behavioral domain. Due to the immersive and possibly multimodal nature of virtual environments the authors provide guidelines and protocols for usability testing and heuristic evaluation of virtual environment characteristics.

Most participatory approaches focus on the inclusion and communication with patients and caregivers throughout the development cycle. For example, Astell and colleagues (2009) describe such method for the design of computer-based support systems with dementia patients and their caregivers. They depict the communication process and the special considerations that are required when working with a user population with cognitive impairments. The authors name their approach user-centered in nature and describe how the user is actually involved in the design and evaluation process. This is a situation where the distinction between different methodologies becomes vague and methods and their respective names overlap.

Participatory design and also co-design have often been described as actively involving the user in the design and development process of a product or system instead of just adapting the outcome to the user's needs. This can be achieved by exploring the user's habits and problems, discovering solutions together and iteratively prototyping solutions with the user until an appropriate solution to the user's problems has been achieved. Spinuzzi (2005) lays out the details of such methodology, its limitations and how it can be evaluated. A systematic co-design approach for designing technologies for users with autism spectrum disorder is described by Francis, Balbo and Firth (2009). In a structured evaluation by a panel of seven autism experts a set of guidelines has been identified that addresses the use of design techniques and co-design management when working with individuals with autism spectrum disorders.

Fidopiastis (2006) and Fidopiastis, Rizzo and Rolland (2010) describe a user-centered design approach by benchmarking immersive technologies before using them for cognitive rehabilitation application. This approach is aiming to increase validity of virtual reality assessments. The authors base their user-centered practices on the ISO13407 guidelines which have since then be revised by ISO9241-210:2010 “Human-centered design for interactive systems”. These standards again put heavy emphasize on understanding and involving the user throughout the iterative development cycle.

All of the described development methods highlight the importance of including the user into the development process, both at the design and testing stages. Each existing publication focuses on specific application areas or user group such as patients with dementia (Astell et al., 2009), autism spectrum disorder (Francis et al., 2009) amputees (Cole, 2006) or cognitive rehabilitation in general (Fidopiastis et al., 2010). It becomes apparent that each clinical domain poses its own unique challenges for the development process, especially with regards to the patients’ ability to partake in the design and evaluation process as outlined by traditional user-centered and participatory design guidelines. Francis and colleagues (2009) particularly highlight this discrepancy by contrasting symptoms of autism spectrum disorders with the requirements for contributing to the participatory design process. The authors conclude that the co-design method can be much more difficult with users with autism spectrum disorders. Though, the selection of appropriate methods and tools that empower the users during the design process can greatly facilitate the designer – user interaction.

It is the purpose of this paper to outline methods and challenges for user-centered design in the domain of neuropsychological rehabilitation. The development of VR applications for neuropsychological training and assessment requires additional design factors to be considered. The overview in the following chapters provides details of such factors and their influence on development, testing and communication between involved stakeholders. An example for applying such framework to a VR assessment for patients with traumatic brain injuries is presented and discussed.

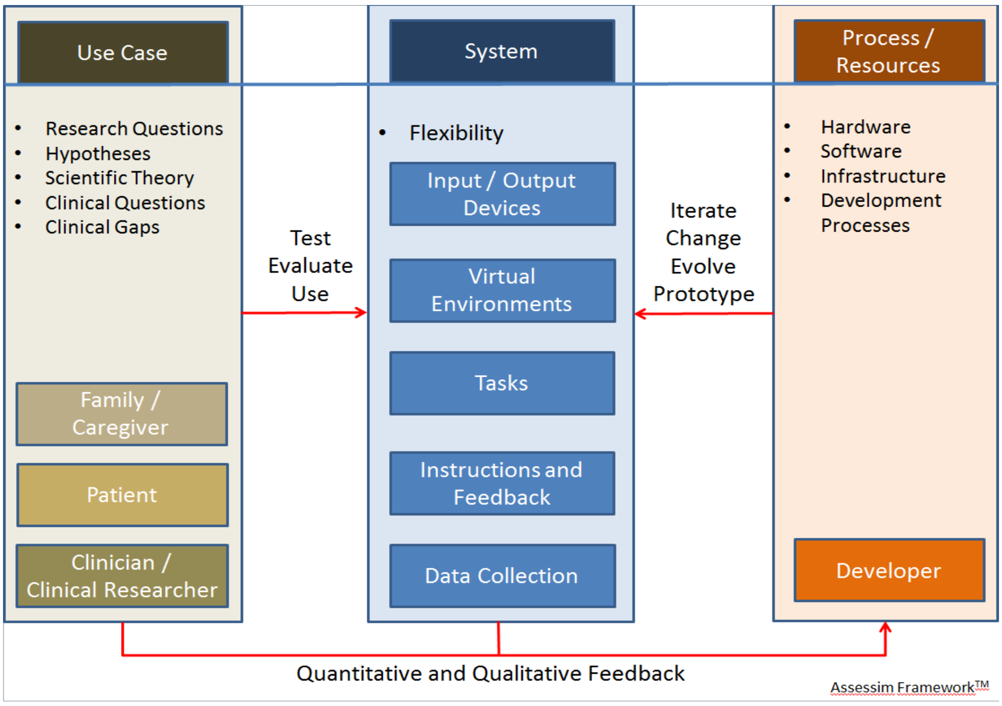
Methodology

Virtual reality technology comes with a well-known set of strengths and limitations (Rizzo & Kim, 2005). Widely available development tools such as game engines and 3D modeling applications lay the foundation for effective workflows to build interactive virtual environments within days instead of months (Koenig, 2012). However, the availability of such development tools does not automatically provide a standardized way of creating applications that solve existing clinical problems. As previously outlined, user-centered and participatory design provides guidelines for user involvement, but the integration of these guidelines into the actual development process – from project inception to finished product – is left to the developer. This leads to the question of how design, development workflow and user integration can effectively be combined to create applications that provide value in the context of cognitive rehabilitation. The following framework provides an outline of such workflow in the context of a virtual reality cognitive assessment.

An initial exploration of research questions, scientific inquiries, clinical questions or clinical gaps can motivate the design and development of an application that addresses an identified problem or opportunity. A developer then chooses the appropriate tools and resources to build a virtual reality system that solves the identified problem. However, a virtual reality system potentially consists of a large number of components that include software and hardware elements. Choices for each component have to be made based on the input from several user groups. This is where a communication challenge starts to emerge which is not accounted for in traditional user-centered or participatory design methods. Depending on the purpose of the developed application, a large number of user groups can be involved in the development of such a virtual reality system. For example, a system might primarily be designed for several members of the clinical team who need to administer the application to a patient. More use cases emerge when cognitive assessment and training scenarios are considered that range from one-off usage at a clinic to long-term exposure beyond the scope of inpatient and outpatient rehabilitation. Moreover, communication with individual user groups can be asymmetric such that input from certain user groups is purposely restricted or prioritized over other groups. Exemplarily, patients' knowledge about a neuropsychological assessment sometimes has to be minimized and limited to usability feedback while clinicians can be more directly involved in the design process. In each case individual user groups can either give direct input on design decisions or indirectly provide usage data to inform design choices for different system components.

With such a wide range of scenarios, it becomes apparent that the development process involves numerous decisions with many unknown variables and outcomes. Figure one lists several system components that can potentially be integrated in order to build a complete virtual reality system.

Figure 1. Development framework for systems of virtual reality training and assessment. Source: authors



During the course of system development each component needs to be flexible. The amount of choices available for each component complicates the planning of system specifications prior to the development effort. Hence, agile development methods minimize the initial planning process and produce a simple working prototype based on early input from relevant user groups. Subsequent design decisions can address system components in an

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iterative fashion while allowing the overall design of the system to remain flexible. This flexibility pays off when system components need to be changed or replaced due to user feedback and once the system's outcome data is analyzed for its validity and reliability. Ideally, each iteration provides new insights and feedback that can guide design and development decisions of future iterations. With short iteration times (e.g. 2-4 weeks) and a strong focus on collecting user feedback, the chances of successfully finishing a project increase substantially. A large body of evidence suggests that agile development can lead to higher project completion rates, especially in complex scenarios where many aspects of design and development are unknown at the outset of the project (Larman, 2004, pp. 63 – 108).

System Description

Assessim Office is a virtual reality cognitive assessment developed in collaboration with the University of Southern California Institute for Creative Technologies and the Neuropsychology and Neuroscience Laboratory (NNL) of the Kessler Foundation Research Center. The application is based on the Assessim Framework and provides a range of realistic tasks for the assessment of cognitive abilities. The aim of the application is to assess cognitive functions, specifically executive functions, in a complex functional environment. The combination of several tasks of different priorities (e.g. rule-based decision task, reaction time task, divided attention task) is expected to simulate challenging scenarios which are similar to the demands that are placed on the cognitive system in a real-world work setting. It is predicted that such ecologically relevant task scenario is more sensitive to cognitive deficits of brain-injured individuals and can predict cognitive performance in real-world settings accurately.

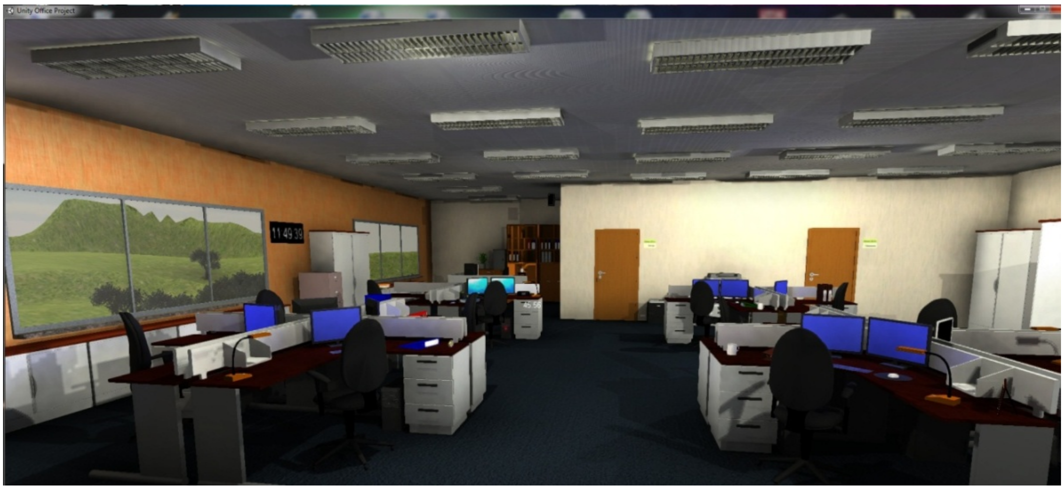
Project Members and Communication

The development of the described framework and its extension for Assessim Office was completed by one virtual reality developer with clinical background. The clinical research team at the NNL consisted of two research scientists, one postdoctoral fellow, three research assistants and several additional staff members. Design decisions were discussed between the virtual reality developer, the research scientists and postdoctoral fellow at the NNL. Direct communication between the developer and the research team consisted of email conversations and Skype calls during which one research scientist was the point of contact for the NNL. Brain-injured patients were only involved in user tests once the initial task design and development were finished. Assessim Office was designed to be a cognitive assessment administered to brain-injured patients with traumatic brain injury. Hence, the early task design was not driven by patient input or user feedback, but rather by scientific theories of human cognition. The researchers at NNL acted as proxies for the patients (Francis et al., 2009) by providing input about the appropriateness of individual system components. A first prototype of Assessim Office was installed on a desktop PC at NNL during an early project meeting. Subsequent updates to the application were exchanged through the filesharing platform Dropbox.

Prototyping

Initial prototypes of the Assessim Framework and Assessim Office were developed over the course of three months. The framework was developed with the game engine Unity and contained a simple event system to trigger object interactions, audio and visual cues. Further, the saving of text files to the local hard drive was implemented. The office environment for Assessim Office (Figure 2) was created with Google SketchUp as outlined by Koenig and colleagues (2011). Before the first prototype was installed at NNL, a menu system and a practice trial similar to the actual assessment session were developed. The total development time for these prototypes was approximately 100 hours, most of which were spent for modeling the virtual environment. The office scene was chosen for its functional relevance, work-related context and relevance for additional projects.

Figure 2*. Virtual office environment rendered in the Unity game engine.*



Each of the system components consisted of a minimally viable solution which is based on lean methods as described by Ries (2011). The goal of the initial prototype was to deliver a simple functional virtual environment to the researchers at NNL. Without any knowledge of how such system can be adapted to the needs of a clinic, research laboratory and patient population, any implementation of features or task content is uncertain and can potentially change several times throughout the development process. The first prototype consisted of mouse and keyboard input, because it was natively supported by the game engine Unity. Output through a standard 24-inch LCD monitor and plug-and-play stereo desktop speakers was chosen due to simplicity, availability and the non-spatial nature of the planned cognitive tasks. The virtual office environment and several simple reaction time and decision tasks (i.e. reply to email, respond to ringing phone, make decision about email offer) were implemented for an unrelated experiment. This implementation was based on a simple trigger system which enables the developer to attach a C# single script to any object within the virtual environment in order to make the object interactive (e.g. turn a monitor on and off). Instructions about tasks or user input were not included, because tasks and input schemes were expected to change over time. Data collection capability was recognized as a fundamental feature needed for any clinical

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trial and was supported through saving and loading text files from the PC's local hard drive. The exact content and structure of the saved files was still undetermined.

Iteration

During December 2011 and December 2012 a total of 22 iterations were developed and tested. On average, the application received an update every 13 days. Average response time between user feedback or design decisions and their implementation in the next update is estimated to be approximately three days. Average development time for each update is estimated to be approximately five hours. Estimations are based on time stamps of file updates and email conversations between developer and point of contact at NNL. However, time estimations are approximated due to developer commitments in several parallel projects. Initial iterations were focused on changes to the task content and user instructions.

Starting after the sixth iteration user testing was extended beyond two research scientists at NNL. Each subsequent update was first screened by the research scientists and later tested with one to two staff members. Each user was encouraged to provide verbal feedback about all system components. A total of seven staff members were tested throughout the development process, three of whom were repeatedly exposed to the application. During these early iterations adjustments to task content, task instructions, audio feedback and user interaction were made.

The ninth iteration added a divided attention task during which the user has to turn a projector on whenever it overheats. The locations of the projector and projector remote control require the user to turn their attention away from their virtual desk on which all other tasks are positioned. This task was also intended to increase overall difficulty of the virtual assessment in order to avoid ceiling effects. Further, user interaction with a joystick was added. It was expected that the navigation through the virtual office was made more intuitive by the use of a joystick. However, early feedback by researchers and several staff members confirmed that using a computer mouse was more efficient and intuitive for interacting with items within the virtual environment.

Iterations nine to thirteen were focused on updates to each of the cognitive tasks. Frequency and timings of phone rings, email responses and decision-making tasks were adjusted to provide an adequate challenge for healthy users. Task events were timed to overlap so that the user had to make decisions on which task to prioritize. Most development time was spent on testing the exact timings of the tasks.

During the thirteenth iteration a major change to the cognitive tasks was implemented. During discussions between developer and researchers it became apparent that the combination of cognitive tasks did provide an adequate pacing but did not measure the underlying cognitive construct that it was expected to measure (i.e. executive functions). Too many reaction time tasks that did not require decision-making or inhibition of false responses were implemented. Within eight hours of development several tasks were removed and a new task was added to the system. This change was made possible by the flexibility of the development process which only required the scripting of the new task within the task component of the outlined system (Figure 1). Answering phone calls was completely removed from the assessment and phone rings were now solely used as distractions. Printing documents was also removed as a standalone task and integrated into the decision-making task. The complexity of the rule-based decision making task was increased to balance the overall difficulty of the assessment. The user now had to evaluate incoming email offers based on several criteria and accept or decline them. Further, based on a different criterion the user had to print the incoming offer and place the printed document at a predefined location. The interference of criteria for both tasks was intended to assess the user's ability for inhibition of dominant responses. A new virtual character was added to the scene to plausibly explain the printing of incoming offers.

During the following iterations minor changes to data saving, instructions and difficulty to the newly implemented task were made. Again, most of the development time was spent on balancing and testing task difficulty. During iteration 19 and 20 the application was first pilot-tested with brain-injured patients. Also, iteration 20 addressed feedback of staff members experiencing dizziness during conducted test trials. Environmental factors and user interaction were discussed with the developer and the rotation speed of the virtual camera was reduced to prevent sudden viewpoint changes. User feedback suggested that the camera moved too fast while the user was getting accustomed to the input scheme during practice trials. Instead of testing several rotation speeds separately a speed control was implemented that allowed the research scientists to change camera rotation speed while the application was running in order to find the optimal setting for users to be comfortable.

After the application was used as an outcome measure for several clinical trials, no major changes to the software were made to avoid jeopardizing the validity and reliability of the collected data. Consequently, iterations 21 and 22 were focused on bug fixing and performance optimization instead of changes to task content.

Future iterations are expected to address bugs and critical feedback once the clinical trials have been finished. Further changes are anticipated once all patients have been tested and validity and reliability analyses have been applied to cognitive task outcome measures. The system's task and data collection components can then be adapted to improve the tasks' validity and clinical value as a cognitive assessment.

***Figure 3**. Extended office environment rendered in the Unity game engine*

Summary

The Assessim Office cognitive assessment has undergone extensive iterative design and testing. During the course of 22 iterations four out of the system's five components have been modified and improved considerably. The system is currently being tested as an outcome measure for three clinical trials at the NNL of the Kessler Foundation Research Center. Four research assistants were trained with the application and are currently administering it to brain-injured individuals. Patients with traumatic brain injury and multiple sclerosis are providing valuable feedback by using the application in conjunction with standardized neuropsychological measures of attention, memory and executive functions. Throughout the design and development process the system remained simple and flexible so that changes for each individual component were easily implemented without affecting other components. Future iterations are expected to further improve the system's psychometric properties and test different options for input, output and data collection. Motion controllers (e.g. Microsoft Kinect, Leap), Head-Mounted Displays and visual data representations (e.g. after action reviews) are planned for future implementation.

Conclusion

Assessim Office is a cognitive assessment that has been designed and developed as part of a framework based on agile and user-centered design. The system is targeted at two user-groups – brain-injured patients and clinicians. Such complex user relationship (e.g. clinicians assessing patients) requires combinations of user-centered and participatory design. Clinical researchers at the Kessler Foundation Research Center were actively participating in the design and testing of the application. Brain-injured patients were only included in user testing after a total of 20 iterations and approximately six months of development. Design and user testing were asymmetric for both user groups because of the evaluative nature of the system and scientific grounding of the task content. The design and development processes were based on elements of agile methods. A wide

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range of changes to each of the system's components were made within only few hours of development. A working prototype was tested shortly after the beginning of the project. Due to the large amount of potential choices for each of the system components, no detailed plan for the finished system was made at the project outset. Instead, incremental changes to individual system components (e.g. input device, task frequency) were implemented and tested rapidly. Assessim Office is currently being used as outcome measure in three clinical trials. Based on patient feedback and results of validity analyses the system's components will likely undergo further iterations.

An extension of the current system is being developed by replacing the virtual environment with a larger office building. The building provides a more complex layout in order to assess the user's navigation ability. Additionally, a large number of interactive virtual characters are added to simulate a realistic, distractive work environment for cognitive assessment (Figure 3). Due to the flexible system architecture such extension only requires a change in art assets and the adaption of the cognitive tasks to the new environment. All other system components remain identical. Consequently, the described framework allows the developer to deploy a large number of cognitive assessments, each customized to a specific environment which is relevant to the assessed patients and users. This approach extends the context-sensitive clinical framework as described by Koenig (2012).

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TELEREHABILITATION FOR STROKE PATIENTS: AN OVERVIEW OF REVIEWS

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Abstract

Background: The increasing number of survivors following stroke events are enlightening new needs to guarantee appropriate care and quality of life support at home. A potential application of telemedicine is to provide home care and rehabilitation. Within the framework of an EU FP7 project called Integrated Home Care (IHC Grant Agreement no: 222954) we performed an overview of reviews on the telefacilities for the homecare in stroke patients.

Materials and methods: A broad literature research was conducted in PUBMED, Web of Science® and The Cochrane Library databases. We included and graded all the reviews according to the following criteria: published in English in peer-reviewed journals, targeting stroke as adult patients (age>18yr.) and considering a homecare setting in the intervention.

Results: 6 reviews were included (i.e. 1 systematic review with meta-analysis and 5 non-systematic reviews). No conclusions can be stated on the effectiveness of telerehabilitation compared to other home treatments, due to the insufficient data available, nevertheless strong indications emerged for the inclusion of “all cause mortality” and “hospital admission” as primary outcomes. Besides “QoL”, “cost”, “adherence” and “patient acceptability” should be included as secondary outcomes, for a complete evaluation of the tele-intervention. No adverse effects were reported in all the reviews, stating that tele-interventions appear to be safe as usual care at home.

Conclusion: Those indications should be considered as relevant in planning a telerehabilitation trial, in order to observe the expected effectiveness from a multidimensional point of view in the clinical, financial and social perspectives.

Keywords: telerehabilitation, stroke, homecare

Introduction

The increasing number of survivors following an acute event like stroke and the consequent improvement in their life expectations are enlightening new needs to guarantee appropriate care and quality of life support at home.

The World Health Organisation (WHO) Europe Regional Office considers as a critical issue in Western-countries the fragmented delivery of health and social services.

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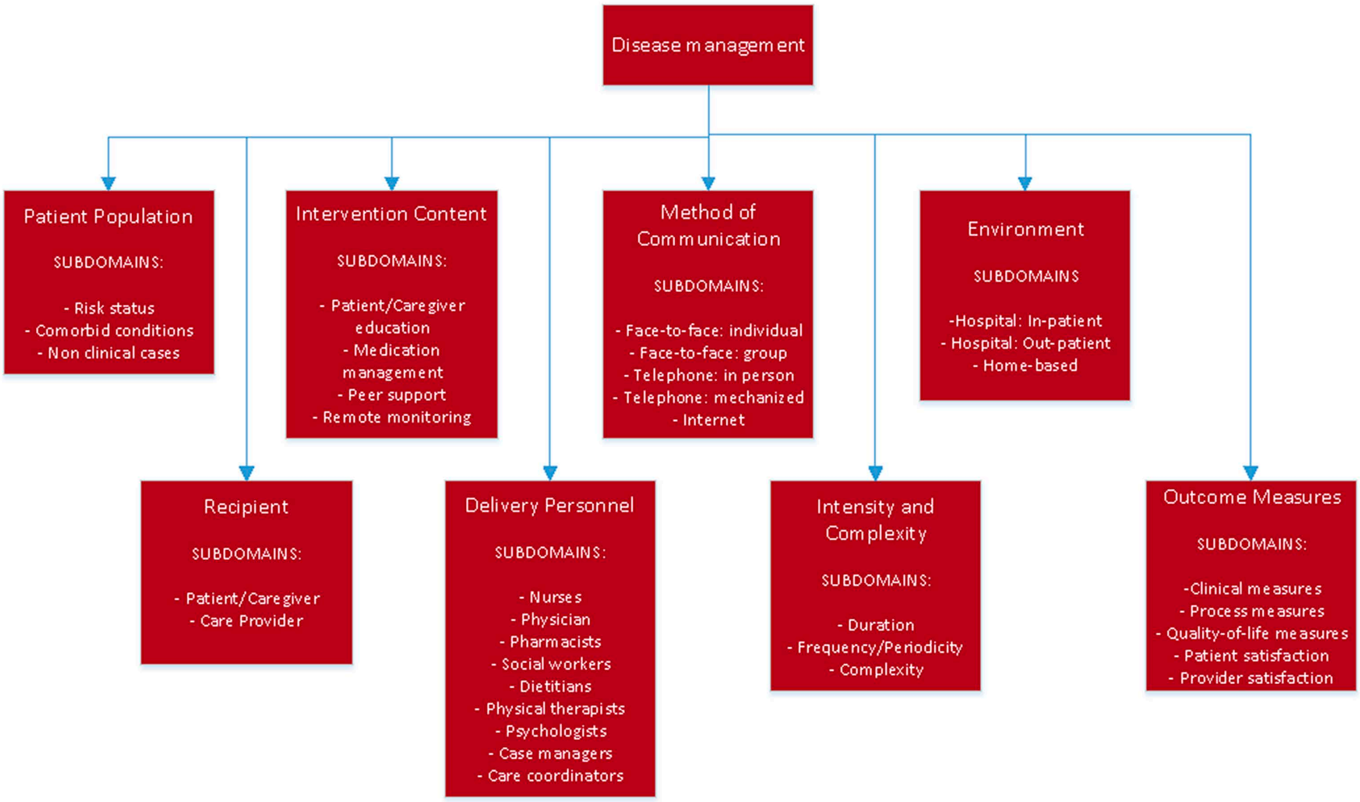
Figure 1. Disease management taxonomy. This diagram appears courtesy of [Krumholz et al., 2006].



Disease management has shown great promise for the reorganization of chronic care and optimization of patient outcomes. Nevertheless, disease management programs are widely heterogeneous and lack a shared definition, which limits our ability to compare and evaluate different programs. To address this problem, the American Heart Association's (AHA) Disease Management Taxonomy Writing Group [Krumholz et al., 2006] developed a system of classification (Figure 1) useful to categorize and compare disease management programs, as well as to identify specific factors associated with effectiveness.

Following the AHA taxonomy we can defined the telefacilities in homecare with a broader meaning like the "home-based remote monitoring and treatment of chronic patients delivered by healthcare professionals, through internet and communication technologies (ICT), with different intensity and complexity, in order to improve both objective and subjective outcomes".

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In recent years, the increasing availability of low costs ICT gave the opportunity to explore the effectiveness of technology solutions in providing health services within and outside the hospitals. This opportunity increased the interest for telemedicine in the rehabilitation – care field, thus the telerehabilitation and telecare are emerging as new branches of the telemedicine [Botsis & Hartvigsen, 2008].

Continuity across primary and secondary settings is mainly assured by integrated forms of care: telemedicine has been advocated as a possible technological, managerial and economic support for health service integration. A potential application of telemedicine is to exploit home care and rehabilitation of people impaired by neurological diseases such as stroke [Craig, McConville, Patterson & Wootton, 1999; Craig, Patterson, Russell & Wootton, 2000].

Telerehabilitation is defined as the remote delivery of rehabilitative services through internet and communication technology (ICT) [Rosen, 2004]. Telemonitoring (i. e. patient functioning assessment and clinical management), teletherapy, teleconsultation, telementoring and teleducation are potential services that can be provided to patients through professionals or caregivers.

A number of trials have been published to primarily test the feasibility of telerehabilitation and telemedicine homecare approaches, as well as to compare their effectiveness to standard home rehabilitation - care [Hermens et al., 2008; Hill, Theodoros, Russell & Ward, 2009; Piron et al., 2008; Piron et al., 2009; Schein, Schmeler, Holm, Saptono & Brienza, 2010].

A Cochrane review [Currell, Urquhart, Wainwright & Lewis, 2000] has already explored the effectiveness of the professional practice and health care outcomes in the use of telemedicine compared to face to face patient care. Nevertheless the authors couldn’t perform a meta-analysis due to the high heterogeneity in the few studies included.

The authors concluded that using telecommunications technologies is feasible, but there is little evidence of clinical benefits, moreover no analysable data exist about the cost effectiveness of telemedicine systems,

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with a consequent warning for the policymaker to recommend a broader use and investment in unevaluated technologies.

In order to understand the actual magnitude of telerehabilitation benefits and eventual harms when compared to standard home rehabilitation/care and to plan with meaningful outcomes a clinical pilot trial on tele - treatment at home in stroke survivors, we have summarized the body of evidence on the telerehabilitation approaches by means of an overview of reviews.

Methodology

Search Strategy

To include the major number of papers on telefacilities in integrated care for stroke patients, a broad search strategy, with no limits applied, was run in the databases: PUBMED, Web of Science® and The Cochrane Library. The following mesh terms were included in the string: “tele*”, “telecare”, “telemedicine”, “homecare” and “stroke” combined with different Boolean operators.

Selection Criteria and Analysis

The selected reviews were included according to the following criteria.

- language of publication was English;
- the targeted populations must include stroke patients;
- the patients enrolled in the study should be adult, namely with an age>18 yrs;
- a home care setting considered in the interventions;
- full-text articles in peer-reviewed journals.

The reviews not addressing telemedicine in stroke patients and focused on caregivers or professionals, instead of patients directly, were excluded.

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To grade the quality of evidences, the included reviews were rated (high, moderate or low) according to the following methodological criteria:

- HIGH: systematic review with meta-analysis;
- MODERATE: systematic review without meta-analysis;
- LOW: non-systematic review.

Descriptive data (author; year of publication; pathologies included; intervention; evidences) was extracted by all the reviews included. The findings were summarized into descriptive tables displaying the main data.

Results

The literature search led to 414 potential relevant records in PUBMED (9,4%), Web of Science® (84.6%) and The Cochrane Library (6.0%) (Table 1).

Table 1. Bibliographic search strategy.

Database	Search strategy	No of articles
PUBMED	tele* AND care AND stroke	39
Web of Science®	tele* AND care AND stroke	350
The Cochrane Library	telecare	5
The Cochrane Library	homecare	7
The Cochrane Library	telemedicine	13

From the overall relevant studies we excluded all those not reporting a review and not published in English, resulting in 49 records whose abstract were screened following the selection criteria. In the end, 6 full-text reviews were included in the overview (Figure 2).

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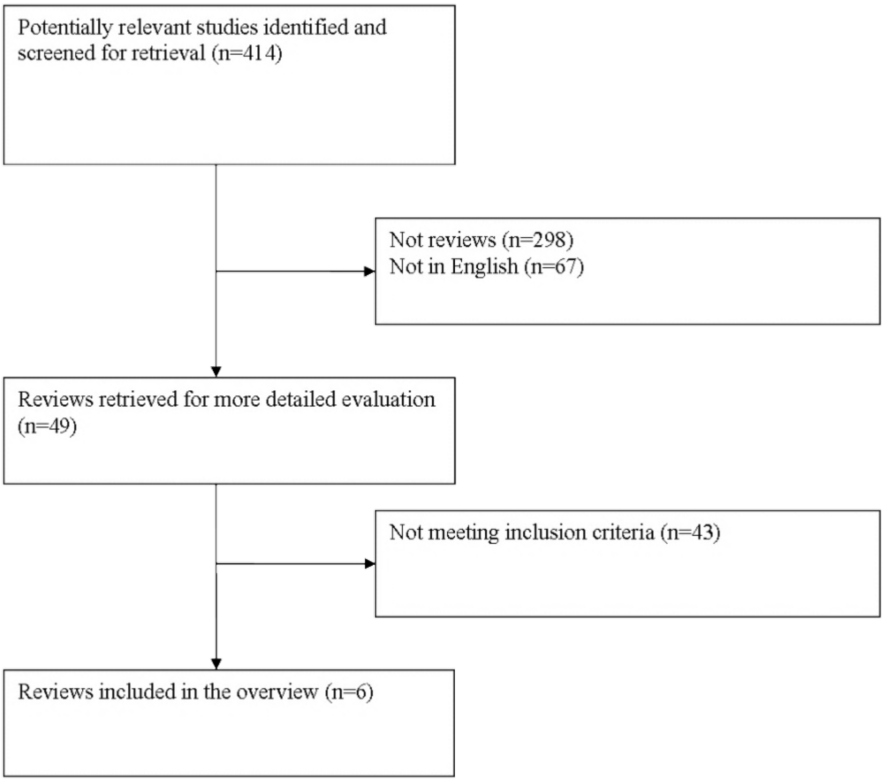
Figure 2. Flowchart of the review process according to the QUOROM PRISMA standard.



Within the records included, the publication year ranged from 2003 to 2006 and the sample was composed by:1 systematic review with meta-analysis (16,7%), 5 non-systematic review (83,3%) and no systematic review without meta-analysis. With regard to the targeted populations, the only systematic review with meta-analysis compared different telemedicine approaches with usual care in stroke and HF patients, while all the 5 non-systematic reviews were targeted only to stroke patients.

Interventions

Different kind of remotely controlled interventions at home were extracted from the analysis of reviews, confirming the outstanding heterogeneity in the available approaches to telecare for the management of stroke diseases after discharge.

It was possible to extract evidence on telerehabilitation interventions for stroke patients intended as:

- telephone follow-up (TFU),
- interaction with devices based on position/sensing technologies,
- remote control of devices based on position/sensing technologies
- remote control and interaction with virtual reality based devices.

Considering the heterogeneity in the different approaches to telerehabilitation interventions, it was not possible to plan a comparison of the results from different reviews.

Summary of the Evidences

High quality evidence

In HF and STROKE patients (Table 2):

Case management interventions providing also TFU were associated with the reduction in the overall mortality in HF patients, especially in high quality study (odds ratio = 0.68, 95% confidence interval 0.46 to 0.98, P=0.04), but it is unclear which are the effective components involved in the case management interventions. Moreover TFU in HF and STROKE patients showed clinically-equivalent results compared to control groups due to the low methodological quality of the studies specifically designed for this comparison. TFU couldn't be associated specifically with the reduced mortality in HF and STROKE patients.

Table 2. Summary of findings from systematic reviews with meta-analysis.

Author	Year	Pathology	Intervention	Evidence
Mistiaen, Poot	2006	HF; STROKE	Telephone follow-up (TFU)	Low methodological quality of the included studies. No adverse effects reported. Clinically-equivalent results between TFU and control groups. Inconclusive evidence about the effects of TFU.

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Low quality evidence

In STROKE patients (Table 3):

- The utilization of telemedicine is recommended to increase the delivery of evidence-based stroke treatments.
- There are still insufficient data about the use of telemedicine in stroke prevention, rehabilitation and post-stroke care.
- Telerehabilitation interventions using VR have been improving post-stroke patients outcomes, however few data are available at this time.
- Telemedicine might become a viable option in remote areas.
- Developing of a successful implementation of a home-based rehabilitation system is making technology reliable and blind to the user.
- Great potential is foreseen if the cost of the system is reduced.

Table 3. *Summary of findings from non-systematic reviews.*

Author	Year	Pathology	Intervention	Evidence
Audebert, Schwamm	2009	STROKE	telemedicine	Recommended to increase the delivery of evidence-based stroke treatments. It can play a critical role, particularly in neurologically underserved areas. Insufficient data in stroke prevention, rehabilitation and care.
Misra, Kalita, Mishra, Yadav	2005	STROKE	telemedicine	In remote area telemedicine may become a viable option
Zheng, Black, Harris	2005	STROKE	Telerehabilitation position/sensing technologies based	Development of technologies reliable and invisible to the user.
Holden	2005	STROKE	Telerehabilitation Virtual Reality based	Needs of reducing costs
Burdea	2003	STROKE	Telerehabilitation Virtual Reality based	Telerehabilitation interventions using VR has been improving post-stroke patients Lack of data is available at this time.

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Conclusion

The state of the evidence emerging from this overview should be considered in planning trials on tele-applications to provide rehabilitation services in homecare. Nevertheless it should be considered that the few indications emerging from the summarized data seem to be weak as based mainly on non-systematic reviews.

In stroke patients, it should be preferred an on-line interactive device (allowing also videoconference) than a store and forward device for providing the tele-intervention.

Primary outcomes like “overall mortality” and “hospital admission” should be included to prove the effectiveness of interventions; moreover secondary outcomes like “QoL, “cost”, “adherence” and “patient acceptability” should be taken into consideration to perform a complete analysis of the chosen telecare-approach.

The above indications should be considered as relevant in trials planning, in order to demonstrate from a multidimensional point of view the effectiveness of telerehabilitation in clinical, financial and social perspective. One of the main issue in dissemination of telerehabilitation mainly relies on the differences in recognizing, by policy maker, this service as a reimbursable one.

Regarding the systematic analysis of the literature, the methodology, in designing studies targeted to stroke population, should improve in order to obtain a more complete framework of the effectiveness of telemedicine as a useful intervention in the homecare of neurological conditions.

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A KINEMATIC GAME FOR STROKE UPPER ARM MOTOR REHABILITATION - A PERSON-CENTRED APPROACH

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Abstract**:** This report describes the possibilities of information and communication technology (ICT) in stroke care, addressing a person-centered care approach. Attention is paid to user involvement, design, videogames, and communication between health care professionals mutually as well as with patients, and how to share performance data with an electronic health record. This is the first step towards a supportive ICT system that facilitates interoperability, making healthcare information and services available to citizen's across organizational boundaries.

Keywords: games, ICT, stroke, upper extremity, person-centered care.Introduction

Introduction

The Swedish health care is currently organized much like a production process, meaning that health is treated as a product. Patients are led through a number of routine based procedures and the goal is that they should come out healthy at the end of the process. This method is efficient when treating emergency patients, but less efficient when treating chronically ill patients. For chronically ill patients treatments could become more efficient by being more adapted to particular needs. This is a challenge also because many different care and nursing units have to cooperate for

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every individual in this patient group. Since the chronically ill continuously utilize the health care sector throughout their life, gains for this patient group could be substantial (Spegel & Olsson, 2011).

Stroke is a common cause of long-term disability in the developed world (Jones, Riazi, & Norris, 2013). The person surviving a stroke demands regular personalized rehabilitation according to the individual problem profile and her/his own choice of engaging training activities. The clinically confined rehabilitation is good but worldwide decreasing in time extent. Community or home-based rehabilitation is increasingly looked to as a solution (The National Board of Health and Welfare, 2011). Upper extremity (UE) paresis is a common problem following stroke and the paretic UE is typically weak, slow, and lacking in coordination and dexterity (Langhorne, Coupar, & Pollock, 2009). Skilled UE performance requires the effective and efficient gathering and processing of sensory information relevant to the task at hand. Research implies that practice on tasks that are automated influence performance and underlie brain activity (Schneider & Shiffrin, 1977), indicating that the premotor cortex plays a role in UE recovery (Johansen-Berg et al., 2002). For the treatment of sensory stimuli in the brain, we have to work out a certain ways in which multiple sensory stimuli, such as motion, visual and auditory information must be coupled. Some studies suggest that video gaming may help stroke patients because of the brain's unusual potential for remodeling, in which it creates new nerve cell connections (Saposnik & Levin, 2011).

The point of departure in the project is with respect to the survivor's continuity of care; the lack of concordance within stroke care. The amount of rehabilitation required to bring stroke survivors to their full potential varies across individual cases. Unfortunately the limitations of conventional health care imply that many stroke survivors do not receive the rehabilitation they require (The National Board of Health and Welfare, 2011). In optimizing stroke care in order to satisfy these demands we propose an ICT solution based on communication, shared decision making and therapy. Therefore, empowerment for self-care management through effective engagement strategies (therapy) represents an essential

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component in this research. It is well documented that poor patient engagement is an important contributor to poor self-care management (de Weerd, Rutgers, Groenier, & van der Meer, 2011; Fjaertoft, Rohweder, & Indredavik, 2011). Thus, engaging stroke survivors as active participants i.e., partners in their own health care will have better outcomes (Ekman et al., 2011). Further, it may take time to adjust with the complexities of being at home to develop stroke survivor's personal resources and strategies (Jones, et al., 2013). The assumption is that such interventions cannot solely be undertaken in institutions but in people's homes, where most of the continuous and daily training actually takes place. Rehabilitation is an essential part in stroke care. In Sweden, stroke care is based on current principles as recommended within the National Guidelines for Stroke Care (The National Board of Health and Welfare 2009). Inpatient stroke care consists of four main phases:

- Initial presentation, recognition and identification.
- Referral and initial assessment, and recommendations.
- Inpatient rehabilitation, admission, assessment, intervention, discharges planning.
- Discharge and follow-up.

In this paper we concentrate on the third stage, which supports inpatient rehabilitation. The requirement for admission to a specialist inpatient rehabilitation unit in Sweden is determined by the need for an intensive interdisciplinary rehabilitation program that cannot be delivered in an outpatient or community setting, along with the need for nursing care and/or medical treatment. Inpatient rehabilitation is provided by an interdisciplinary team, offering the full range of specialist assessments and interventions. The team includes the following specialist: clinical neuropsychologist, nurses, occupational therapists, physiotherapists, rehabilitation medicine physicians, speech and language therapists, social workers, and administration support. To identify appropriate management strategies to guide stroke care and to coordinate goals and planned activities from all involved actors, a plan of care is usually established. The plan of care is based on needs identified in the pre-discharge stage, a written

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document which provides an agreement between stroke survivors, their families and health care professional on how to manage day-to-day rehabilitation (The National Board of Health and Welfare, 2009).

The present work addresses the increasing demand on co-operation between different care units, maintaining the continuity of stroke care. Further we wanted to explore the usability of a videogame for UE rehabilitation among occupational therapists (OT's) and stroke survivors.

Methodology

Subjects

The study was carried out at Sahlgrenska University Hospital, neurological rehabilitation unit, Gothenburg, Sweden. Stroke survivors were identified by occupational therapists (OT`s) working at the neurological rehabilitation unit. OT`s were defined as anyone with a significant professional involvement with stroke survivors as part of their day-to-day role. A workshop was organized to investigate the perception and technology acceptance of the OT considering gaming for UE rehabilitation. The first two authors gave a brief introduction of the research study through a short presentation followed by an introduction of the interactive videogame, starting from the very basics of the game play.

System Components

A prototype video game was developed for UE rehabilitation, using Microsoft's Kinect gesture control device on a PC. Using its depth, image, and audio sensors, the device translates user's physical gestures into on-screen actions. In the prototype video game players were presented with a series of colored boxes that could be struck using one of their upper extremities (UE). The boxes moved sideways from right to left on a computer screen and when a box had crossed the vertical center line on the computer screen, the box changed color from bleu to red. At the same time as a box (black circle) crossed the centerline a new box would fly in (dotted circle), see figure 1. In order to gain feedback (hits) the player had to strike (grasp) the red boxes, i.e. the motion of one arm hitting into the air towards the red box on the computer screen. To acquire hits, the red boxes had to disappear, and an alert, hit or miss (voice feedback) appeared. A command line interface was used as the user interface, i.e. typing in commands to start the video game and adjust game parameters.

Usability Evaluation and Play Testing

Information from OT's true interview and usability trials of the prototype game were gathered. The interview included the following questions. (1) Was the game relevant for OT's? (2) Was the game relevant for UE rehabilitation? (3) Was it easy or difficult to find game information on the computer screen? (4) Was it easy to remember how to restart the game?

Design and Development of a Model for a Healthcare Platform for Distributed and Mobile Use within Stroke Care

A healthcare platform was created with a set of generic care components with a patient-centered approach to support stroke care to improve effective care coordination and quality using a plan of care directly related to management of activities and catching of results of specific activity instances. Hence, the information was structured so that it could be used in different contexts, for different purposes, in the health care process and for monitoring and managing activities. The model reflects the principles as recommended by the National Information Structure (2012) which ensures that the correct information is documented and put into context on the general level (Johansson, Wohed, & Kajbjer, 2009).

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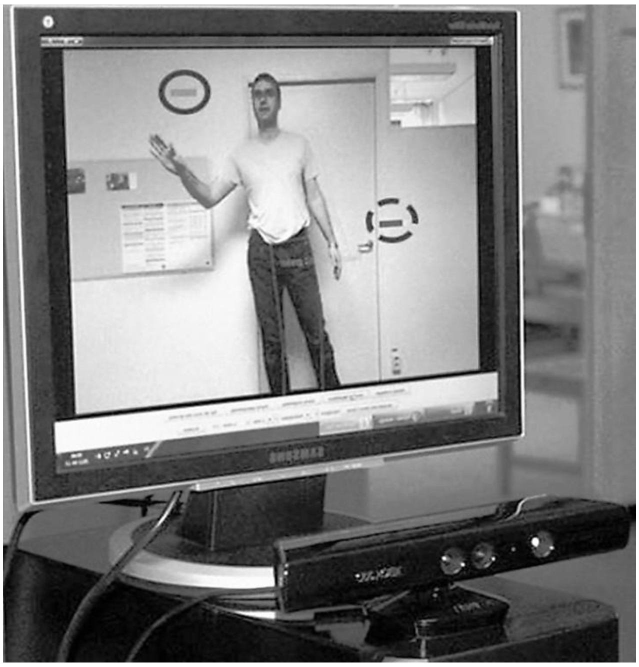
Results

Usability Evaluation and Play Testing

Fourteen occupational therapists (N = 14) and four inpatients participated. The prototype was revised during spring 2012. The major problems identified such as how to begin and stop, data entry, continue data entry and label information was found by 80 %. These problems were addressed and corrected by modifying the interface to make the data entry and labeling more intuitive. In general, this usability test uncovered functional and interface design flaw. The OT's and patients pointed out the following criteria as very important:

- Games should have properties that are relevant to therapists and that can be both manipulated and measured.
- Games should target various body movements; it's best if these can be assessed for quality of movement.
- Motor demands of the games should change independently from cognitive demands.
- The game should accommodate both sitting and standing positions.

Figure 1. A screenshot from the player's perspective, in the upper right corner reaching for a red box (black circle) and at the bottom left corner a blue box (dotted circle) flies in.



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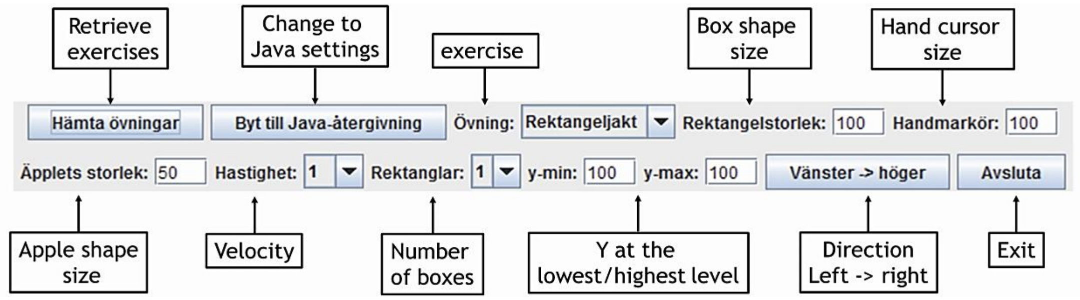
Figurer 2 illustrates the user interface with different labeled buttons for retrieving different exercises as well as varying the dimensions of the hand cursor and box size (upper part of the figure). The lower part displays game parameters true drop-down lists, such as different settings for how fast the rectangles move, how many rectangles appear on the screen simultaneously and the minimum/maximum height the rectangles.

Figure 2. The user interface after the prototype was revised

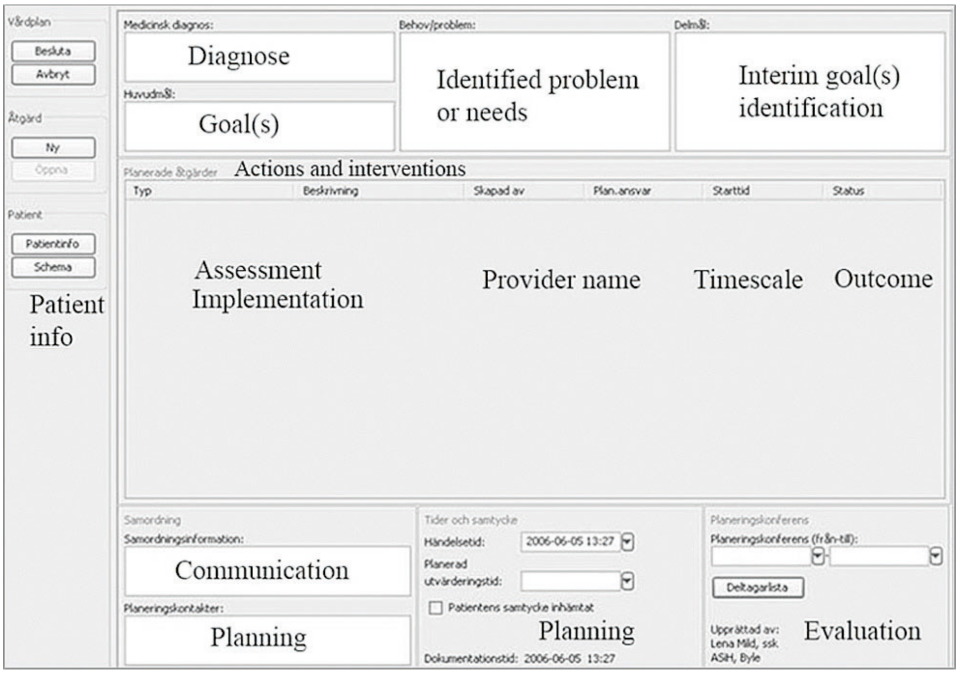


Specific instructions for each player to start the exercise were given, “Imagine that there is an invisible button in front of you, now raise your arm and press your hand in the air”. Once the program has seen your hand, it says "Now I see your hand" and a red circle (hand cursor) pops up on the screen in front of the player at height of the hand. The hand cursor is resizable. Should the program lose the hand, it says that "now I do not see your hand anymore”. For the program to see the hand again one has to press the hand in the air again. The program answers "now I see your hand".

Strategies to Provide an ICT Environment to Support a Patient Oriented Process and PCC Planning

An iterative modeling approach based on different user perspectives, resulted in an interacting model with a structure described in terms of the rehabilitation process for stroke care. The plan of care (Fig. 3) shows activities such as diagnoses, goals, interim goals, planning, assessment, implementation, and timing, use of resources, responsibilities, evaluation and communication. Targeting time priority for activities formulated, each team member has a clearly defined role appropriate to their individual skills. Further, activities can undergo different stages or status changes: proposed; accepted, started, interrupted, or complete. The model developed has its foundation in the individual needs for stroke survivors to high-quality care interventions and professional needs for collaboration between different healthcare professionals and organizational levels.

Figure 3. A Screenshot of the plan of care covering healthcare activities.



Furthermore, the plan of care can include many efforts over a long period. Condition changes for the individual will lead to an updated plan. Results from each activity performance (instance) can be collected for follow up activities in the patient oriented process. Support and definition of activity types will allow data collection and interpretation from the game sensor components for clinical interpretation and use in relation to the care plan. All activity types are defined and structurally and semantically related to the care plan. Each care plan is individual oriented. All activity instances are related to the activity types. In this way all activities can be planned and followed up in terms of time and results. Results for each activity instance can be collected by a specific movement activity type component and reported to the generalized activity component, to be able follow up results for the individual. The follow up is performed in a person centered collaborative way with support of the team. A video mediated modular and integrated communication tool set is allowing different types of professional actors to support the individual by remote synchronous communication to

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the home for support in performing the intervention activities in the right way and to encourage the individual in continuing the intervention activities. Other actors such as relatives and other individuals in the same way can participate in performance of the intervention activities for motivation and social networking.

Discussion

An important and central part of this work is user involvement, in this case representing OT colleague in occupational therapy at Sahlgrenska University Hospital. The acceptance level tended to be high. This was in line with an earlier survey among the OT's, although barriers were identified that hinder its use (Haixia, Zeller, Sunnerhagen, & Broeren, 2012). Thus integrating video gaming as a part of clinical practice requires user involvement. Correctly formed design, with adequate user/OT's goals on what can be achieved increases the likelihood that video gaming is used in routine clinical practice. User's goals can be for example that they easily get an overview of certain information or that they will not feel stupid when they use the system. The OT's goals can be for instance the effect on motor function that one would be achieved by placing the videogame in use. Further we focused on improved access as a critical enabler for effective patient engagement. The strategy was to create and collect information along the patient-centered process that included goal relevant activities, i.e. assessments, foresight, individual's condition over time etc. The model provided information defined as in the inpatient rehabilitation process, according to the National Guidelines for Stroke Care in Sweden.

The game is based on motor planning and feedback, i.e. figuring out how to get one's UE to carry out the goal for motor action. Execution is the actual performance of the planned action. The planning and sequencing of a motor task is based on a person's body scheme; that is, an awareness of UE, and how they move through space. The synchronization between movement and sensory stimuli, i.e. reaching for a visual object in which timing, coordination and sensory information is incorporated. Further there is a combination of bimanual task involved. For instance, bimanual training has been shown to benefit motor performance after stroke (Lin, Chen, Chen, Wu, & Chang, 2010). The next step will be integrating auditory feedback and monitoring movements. Recent research suggests that auditory cueing could lead to an efficacious technique that improves movement coordination (Chen et al., 2009; Zatorre, Chen, & Penhune, 2007). In addition, the observation of a movement on a television screen activates motor areas of the brain that have been damage due to a stroke (Ertelt et al., 2007). This seems to have clinical relevance for stroke rehabilitation, because the same area of the brain is activated when a person sees someone else perform a movement that is automated affects underlying brain activity. Neurophysiologic basis for this recruitment relies on the discovery of mirror neurons (Rizzolatti & Craighero, 2004). These neurons discharged when an animal performed an object-related task with the hand or the mouth and when it observes the same or a similar task done by another individual. These results suggest that mirror neurons are involved in the coding of goals through action (de Vries & Mulder, 2007).

The purpose of this study was to describe, conceptualize and analyze healthcare information and services from the point of view of citizens. In other words, in this study, existing concepts and theoretical models describing healthcare are explored. We defined an information structure that facilitates interoperable, supportive ICT systems with access to information across organizational boundaries. The effective use of resources of complex healthcare data the concept of scalability becomes evident. A scalable system can handle increasing numbers of requests without adversely affecting response time and throughput. Moreover, registry functionality incorporating care plan templates with customizable appropriateness would give the possibility to visualize different care teams and place them along a health-care continuum. A further option would be the ability to have ongoing dialog between multiple caregivers related to an extended process oriented EHR. Moreover, user involvement is one of the key factor for successful ICT implementation and acceptance and resistance are crucial factors in adoption of information system (Gagnon et al., 2012).

Conclusion

Increased knowledge in self-care management strategies true participation in shared decision making will enable stroke survivors to take charge of their own care. Through sharing parts of the EHR, information could be used as a teaching tool to encourage patient's engagement and partnership. In this way advanced technology as movement recognition, exercising in virtual environments, and remote supervision can be used and relate to a PCC process using structured information.

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APPRECIATING SPEECH THROUGH GAMING

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Abstract: This paper discusses the Speech and Phoneme Recognition as an Educational Aid for the Deaf and Hearing Impaired (SPREAD) application and the ongoing research on its deployment as a tool for motivating deaf and hearing impaired students to learn and appreciate speech. This application uses the Sphinx-4 voice recognition system to analyze the vocalization of the student and provide prompt feedback on their pronunciation. The packaging of the application as an interactive game aims to provide additional motivation for the deaf and hearing impaired student through visual motivation for them to learn and appreciate speech.

Keywords: speech recognition, hearing impairment, speech training

Introduction

Hearing impairment can happen to any child, be it by biological or circumstantial cause. Since speech is learned by children through emulating the sounds that they can hear, people tend to assume that if you cannot hear spoken language, you are unable to learn and use it.

It is a common misconception that the hearing-impaired cannot speak (Schwartz, 1987). In reality, there are some oralists in the deaf community. Through specialized teaching techniques, such as emulating how the mouth and tongue are shaped to produce certain sounds, even deaf people can learn to speak. Children with hearing impairment can, with proper training

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and early intervention, overcome their difficulties, be taught and aptly trained to speak.

Most of these training techniques, however, require one-to-one interaction between teacher and student, limiting class sizes. A way around this would be through the use of a voice recognition system, in particular the SPHINX-4 (Walker et al, 2004) Hidden Markov Model speech recognition system, to listen and evaluate the speech made by children.

However, some deaf and hearing impaired students choose to stick with sign language, even if speech is being taught in their school. This is influenced by hearing-impaired individuals' belief that speech is for a 'hearing society' (Goode, 2005). The long and hard training the existing educational system uses to teach speech does not help either. This notion causes the 'deaf society's' further 'isolation' from society (Sadural, 2009).

Those who chose to break out of their stereotype are better able to integrate themselves into mainstream society better than their non-oralist counterparts do. This often results to a better lifestyle and more opportunities in the future (Sadural, 2009).

Speech appreciation, then, plays an important role in this aspect. Simply put, speech appreciation is the clear perception or recognition of the use of speech. Speech appreciation is an unacknowledged factor in a hearing-impaired student's choice of communication mode. It directly affects the intention of the student to perform the speaking behavior (Sadural, 2009).

In light of these facts, SPREAD (Di, Gloria, Reyes, Quiniquini, 2010), or Speech Phoneme Recognition as an Educational Aid for the Deaf and hearing impaired child, is a gaming application that attempts to provide a mechanism to motivate these children to learn speech. Through a system of visual rewards, the game motivates them to try their best at their training and at the same time enjoy and appreciate speech.

Methodology

SPREAD (Di et al, 2009) is an application that, from a functional perspective, simply accepts utterances made by a user, passes the utterance to Sphinx-4 for recognition, and then displays the result. We will describe the system architecture of SPREAD in line with a typical use scenario.

The first thing a child sees when using SPREAD is the Flash-based front-end in a web browser. The child will be shown a series of simple words he or she is to pronounce. 'Apple', 'Bat', 'Star' are a sample of such words. Only one word is shown at a time. Words are also grouped into difficulty levels; higher level words can only be accessed upon completion of a lower level. Figure 1 shows the user interface for this section.

Figure 1. SPREAD main user interface

When the child is ready to pronounce the word, he or she must press the RECORD button so that the computer will record the child's attempt. Pressing the button activates the microphone as well as a Java applet which is responsible to recording the child's speech and saving it into a .wav file.

Once recording is done, the Java applet sends the recording over to the server for speech recognition. Once the .wav file arrives at the server, it is passed into the Sphinx-4 recognition engine. The server then compares the recognition result generated by Sphinx and then compares it with the

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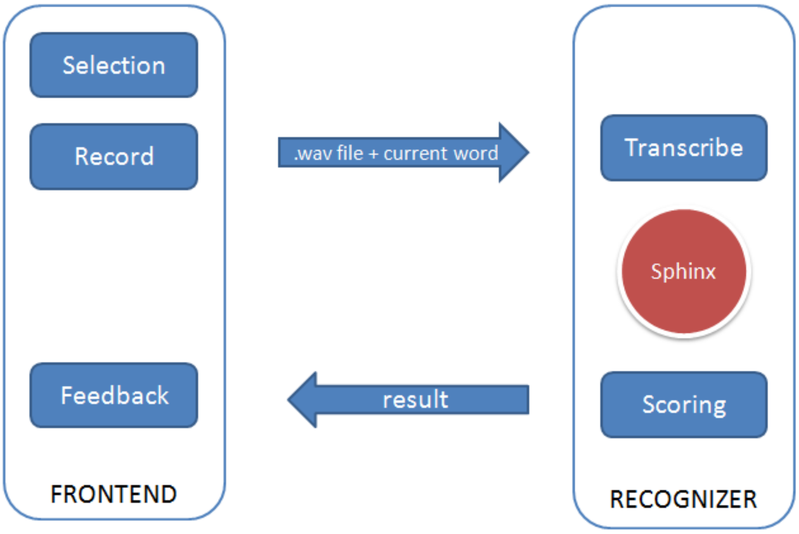
expected result. After determining the appropriate response, the server sends back the result information to the client via the Java applet. The applet then communicates with the Flash front-end to display the result.

A summary of this typical use scenario can be seen in Figure 2.

Figure 2. Functional Diagram of SPREAD



As stated earlier, SPREAD is a simple application from a functional perspective. However, with the target audience of the application being children with hearing impairment, the user experience must be designed in a way that would motivate the child to learn and appreciate speech. In the course of this work, the user interface, scoring system and the result screen are discovered to be what would make or break the speech training of the child. We will discuss these in the Results section of the paper.

Results

This section narrates the experiences gained through the exposure of SPREAD with members of the hearing impaired community. Central to this discussion is the need for an improved feedback mechanism that would effectively grade the response of the child.

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Exposure to Hearing Impaired Adults

SPREAD was initially deployed for use with adult members of the deaf and hearing impaired community (Di et al, 2009), in particular, members of the Support and Empower Deaf Children, Inc. The subjects were completely deaf individuals who were not born deaf and are able to vocalize some words.

Initial feedback was very positive; the subjects were very motivated to try out the game and have expressed the wish to have had this application when they were still in school. Successful trials were even met with cheers from the subjects and their audience.

Enthusiasm to the game actually emerged as a problem as well. The excited users could not help but yell into their microphone, distorting the saved waveform data. This is in addition to the cheering audience adding noise to the data. The distorted data was difficult to be recognized by SPREAD, and even though the pronunciation was correct, SPREAD gave a negative result. Strategies to solve this can include automatically adjusting the microphone volume, giving warnings for too loud/noisy environments, or to simply to have a teacher present to guide the student into the proper use of the microphone.

This initial test also showed some urgently needed modifications to SPREAD. The first version of the application simply displayed positive/negative results (i.e. 'You got it!'/'You didn't get it…'). The negative results affected the subjects visibly, showing their embarrassment and frustration. A partial scoring mechanism was determined to be a way forward from this situation. This is discussed in a later section.

Exposure to Hearing Impaired Children

SPREAD was next deployed for use in the Special Education (SPED) division of the Batino Elementary School of Quezon City, Philippines. Unlike the adult subjects, the children were hesitant to use the software. Out of the 40 subjects, only 5 volunteered to take part once they were placed in front of

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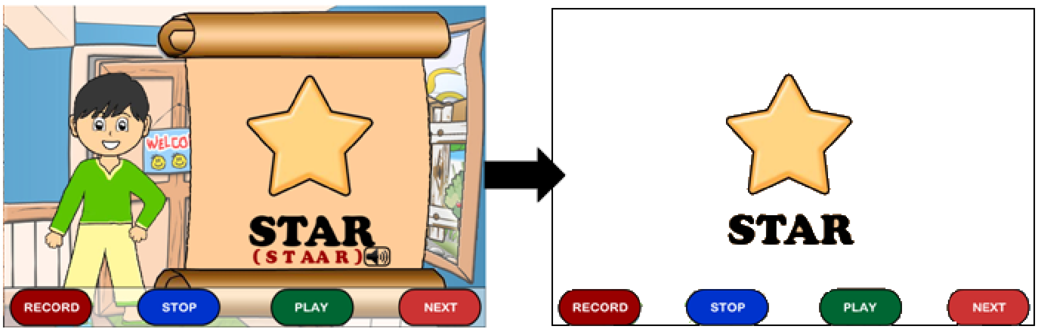
the computer. The researchers noted the shyness of most of the students; it took a little bit of coaxing to get even the five to try out the software.

It became apparent that the children did not know some of the words. Although they are able to sign most words, they were only able to speak only the very common words such as 'Car' or 'Star'. The volunteers actually treated the application as a sudden surprise test that they were not prepared for. At the end of the trials, the students were able to recite conversational messages like 'Thank you' and 'Goodbye' better than how they pronounced the words in SPREAD.

This result indicates that the students encountered in this particular test learned speech more for its utilitarian aspect rather than as for casual conversation. Simple greetings only require a limited vocabulary of spoken phrases. In casual conversations, these children opted to use signing rather than memorizing a large vocabulary of spoken words. SPREAD can be modified in the future to test out these short phrases.

There is a need too for SPREAD to be integrated with the existing speech curriculum. The students tested were unprepared for the recitation of the particular words being used by the game. SPREAD would be more effective if the words being shown to the students were just taught by their teacher or as a post lesson evaluation tool.

Figure 3. Simplified User Interface



The feedback screen also needs to be, at the least, reworded. The 'You didn't get it…' message came out as too negative for some of the users, adding to their frustration. It was recommended that instead a 'You can do

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better!' message or 'Good try!' message would lessen the brunt of a wrong recording session.

On Scoring

To discuss the scoring mechanism of SPREAD, we have to first discuss how Sphinx evaluates sound data. Given the sound file, Sphinx first compares the sound with stored sound samples from the acoustic models. These stored sound samples are called phonemes, which are the basic building blocks of a spoken word. Sphinx actually produces multiple results as it tries to determine which best phoneme combination closely matches the inputted sound.

To help with the evaluation, Sphinx uses a grammar file. This grammar file tells Sphinx what particular words are expected to appear and in what particular combination. This limits the possible outcomes that come out of the decoding process. By default, Sphinx will always produce as an outcome one of the possible words in the grammar file. After Sphinx produces the best matched word, SPREAD then compares the decoded word with the expected result. If these two do not match, then SPREAD will send a negative result to the front end module.

Unfortunately, this particular scheme does not give partial points. An alternative scoring system was attempted wherein the speech was deciphered at the phoneme level instead of on a word level (Carreon, 2011). The scheme was to provide full points if all the correct phonemes of the word were pronounced correctly, partial points if the 'training phoneme' appears (in contrast to 'training word'), and a negative result if the training phoneme was not detected at all.

This scheme, however, resulted in lower recognition rates. On a per word level, Sphinx can compare the detected phonemes and match it to the closest possible word; this eliminates noise and other ambiguities as the set of possible results is only limited to a few words. The set of possible results expands exponentially on a per phoneme level as Sphinx can no longer get

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any contextual clues from the grammar file and simply returns any and all phonemes it can detect.

This area is the current focus of the research. The use of the Sphinx confidence score metric seems to be a promising avenue for exploration. A simpler scheme would be to record multiple trials of the same word return how many were detected correctly vs. the total number of trials.

Conclusion

This paper discussed SPREAD and how it uses gaming as a strategy for motivating a hearing impaired child to learn how to speak. In the course of the research, it was shown that SPREAD can and does promote speech appreciation, though improvements with the user interface and feedback mechanism would have to be addressed in the near future.

Development for SPREAD is still continuing. The end goal for SPREAD is for it to be deployed as a teaching tool working in line with the traditional methodology for teaching speech. It aims only to enhance the learning experience of a child and not to supplant nor to totally replace the need for the standard speech training being done in oralist schools. SPREAD can also be made as a platform for other types of gaming strategies above and beyond this simple object identification scheme. It is hoped that this work will inspire others to explore this promising field of research.

Acknowledgments

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WEB-BASED HOME REHABILITATION GAMING SYSTEM FOR BALANCE TRAINING

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Abstract: Currently, most systems for virtual rehabilitation and motor training require quite complex and expensive hardware and can be used only in clinical settings. Now, a low-cost rehabilitation game training system has been developed for patients with movement disorders; it is suitable for home use under the distant supervision of a therapist. It consists of a patient-side application installed on a home computer and the virtual rehabilitation Game Server in the Internet. System can work with different input gaming devices connected through USB or Bluetooth, such as a Nintendo Wii balance board, a Nintendo Wii remote, a MS Kinect sensor, and custom made rehabilitation gaming devices based on a joystick. The same games can be used with all training devices. Assessment of the Home Rehabilitation Gaming System for balance training was performed on six patients with Cerebral Palsy, who went through daily training sessions for two weeks. Preliminary results showed balance improvement in patients with Cerebral Palsy after they had completed home training courses. Further studies are needed to establish medical requirements and evidence length.

Keywords: rehabilitation, game, balance disorders, cerebral palsy.

Introduction

Recent experimental evidence suggests that virtual reality technologies have great potential in the neurological rehabilitation of patients suffering from movement and balance disorders (Adamovic et al, 2009). Recovery of motor skills depends on neuroplasticity that is driven by repetition, intensity, motivation, and task-oriented training. Currently, there are many different systems designed for virtual rehabilitation and motor training, but most hardware is quite complex and expensive and can be used only in clinical settings. Low-cost, commercially available gaming systems such as Nintendo Wii and Xbox Kinect are widely used at home and have a high potential for movement training (Deutsch et al, 2008). However, such typical games are too difficult for neurological patients, whereas therapists have no means to carry out distant supervision of home training sessions. For more than twelve years, specially developed rehabilitation games with gaming devices have been used at our International Clinic of Rehabilitation in order to stimulate motor training in patients with Cerebral Palsy (CP) (Kachmar et al, 2001). Now, gaming rehabilitation has become one of the components of the multimodal rehabilitation system and is used on a regular, daily basis (Kozyavkin et al, 2004). However, movement training should be continued in home settings after the patient has been discharged from the clinic.

The objective of our work was to develop a low-cost rehabilitation game training system for patients suffering from movement disorders, which would be suitable for home use and under the distant supervision of a therapist. The second aim was to make a preliminary assessment of its benefits for training balance in patients with Cerebral Palsy.

Description of the training system

The Home Rehabilitation Gaming System was developed to provide game training at home under the supervision of a therapist. It consists of two main parts: a) a patient-side application installed on a home computer – the Game Device Controller (GDC), and b) a virtual rehabilitation Game Server in the Internet. The GDC main functions are to connect gaming hardware, convert data from different hardware to one format, send the game controlling data to the games, and receive feedback.

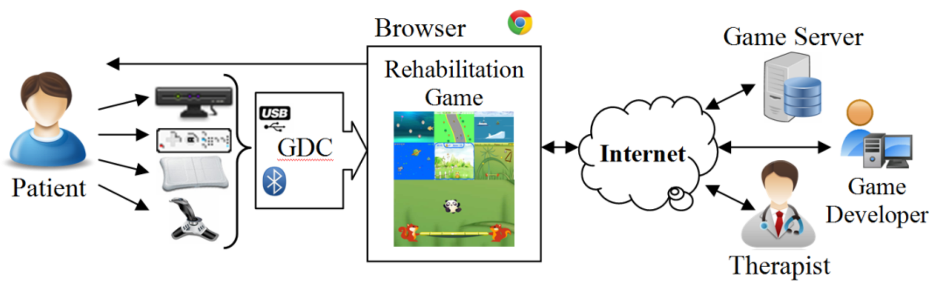
In our system, GDC can work with different input gaming devices connected through USB or Bluetooth: a Nintendo Wii balance board, a Nintendo Wii remote, a MS Kinect sensor, custom-made rehabilitation gaming devices based on a joystick, and several other. Such an approach allows us to use the same games with all training devices and not develop separate games for each device. Of course, there are some restrictions for game scenarios, and games for disabled persons should not be too complicated.

The virtual rehabilitation Game Server performs the following tasks:

- *User management* – there are different types of users: the patient, therapist, game developer, and systems administrator, all of whom have different interfaces and access rights to the system.
- *Repository for rehabilitation games with training guidelines* – there are instruction for each game, including required gaming devices, training positions, and a short game legend.
- *Usage statistics* – stores and presents graphs on data about game scores, the duration and time of each training session.
- *Messaging* – message support exchange between patients and therapists.

The general structure of the system is presented in Figure. 1.

Figure 1. Scheme of the Web-based virtual rehabilitation system.



Rehabilitation games

Rehabilitation games is the most important component of the home training system. They should be rather simple, appropriate for the person with

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movement disorders and, at the same time, entertaining and fun enough so that the training process does not become boring. Widespread tools, such as the Adobe Flash platform and AS3 language have been selected for game development. A special game user interface was implemented to simplify adding new games to the system and testing them with different training devices. Since the system is multilingual, the game messages are not included directly into the games, but are obtained from the server, depending on the language selected during registration.

Figure 2. *Screenshots of rehabilitation games.*

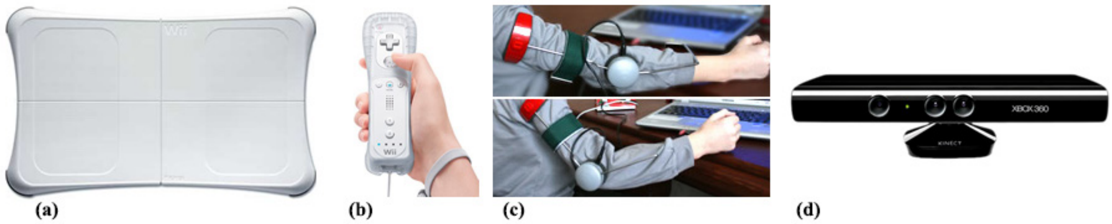
Typically, patients with motor disorders have a limited range of motion. Therefore, before the training session starts, each game is calibrated according to the patient's individual possibilities. He/she needs to perform one or two movements within maximal range and later, games will require the patient to carry out movements that are appropriate for his/her abilities. Each game has five levels of difficulty. The first level is quite simple so that even patients with significant movement disorders are able to complete it. Each subsequent level requires more accurate and faster responses. The complexity of the last level is appropriate for a healthy child aged seven to eight years.

A unified scoring system is used in the games. A completed first level earns the patient ten points, the second – fifteen, the third, fourth and fifth – twenty-five points each. The maximal game score comes to 100 points. The score, time, and duration of each gaming session are stored in the database. Currently, there are six games in the system and our team continues working on new ones. Several game screenshots are presented in Fig.2.

Rehabilitation gaming hardware

The following types of rehabilitation gaming hardware are used in the home training system: a) Nintendo Wii balance board, b) Nintendo Wii remote, c) Universal Gaming Device, d) Microsoft Kinect motion sensor.

Figure 3. Rehabilitation gaming hardware used in the system: a) Nintendo WII balance board b) Nintendo WII remote, c) Universal Gaming Device, d) Microsoft Kinect.



The Nintendo Wii balance board has four pressure sensors located in each corner of the board; information about center of pressure displacement is transmitted to the computer over the wireless Bluetooth connection. Balance training exercises are performed in different positions: standing, sitting, kneeling, etc.

The Nintendo Wii remote has two accelerometers, making it possible to define its inclination in the gravity field. The Wii remote, attached to a patient's body part, transmits information about its position. For example, if the remote is attached to the patient's chest, the games can be played by bending the body sideways.

The Universal Gaming Device is a custom-made simple electrogoniometer developed at the International Clinic of Rehabilitation. It can be used for tracking movements of elbow, wrist, knee, and ankle joints. Two levers of the device, attached above and below the joint, track flexion/extension movements and are used to control the game.

The Microsoft Kinect motion sensor tracks all body movements. However, in our training system, we choose to track only one or two body parts that are aimed for training. These body parts and required movements are defined in exercise setups and are used for game controlling.

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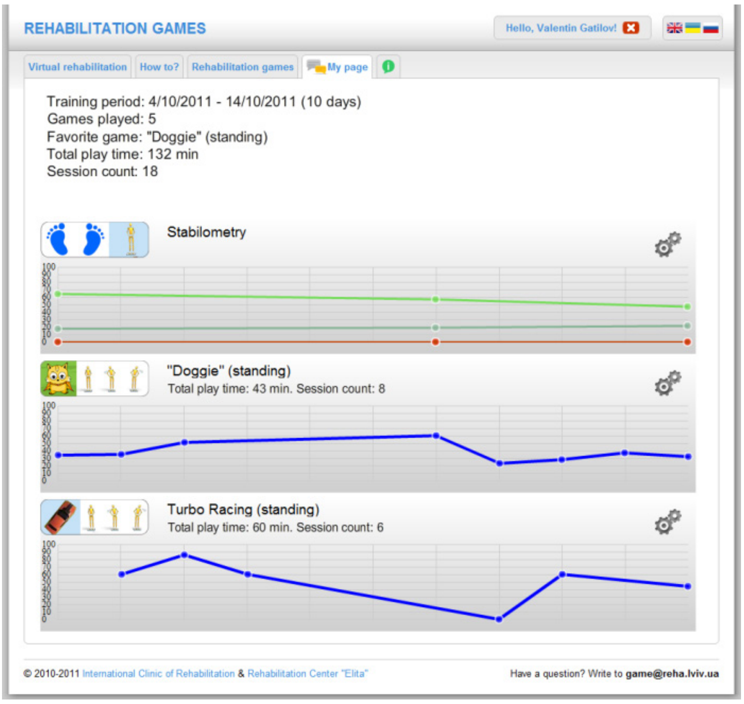
Home training

Before starting home training sessions, the physical therapist evaluates the patient and draws up a relevant training program, indicating recommended games, training positions, and the frequency and duration of sessions. He registers the patient in the system and trains the child and his parents how to use the system.

The patient or his/her parents should ensure that they have all the required hardware at home; they should download and install Game Device Controller software on the computer, and check the connection of gaming hardware to computer. After setting up the home computer, the patient logs in to the system on the Web-page, selects the recommended games and starts his/her training session. Information about the duration and time of the gaming sessions, as well as game scores are stored in the system and can be viewed in the form of graphs. This information is accessible to the therapist so that the program may be adjusted, if necessary.

Figure 4. Results and duration of the training sessions are presented as charts.



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Balance training exercises

The Game Training System can be used as a supplementary treatment option for patients with different motor problems. This article describes its usage for patients with balance problems. Currently the system is available at http://game.reha.lviv.ua/.

A personal computer with an Internet connection and a Bluetooth adapter, a Nintendo Wii balancing board, and a Nintendo Wii remote are required to conduct home balance training exercises. Balance training exercises are aimed at developing coordinated left-right and forward-backward weight-shifting skills and maintaining position. The patient stands or sits on the balance board; while performing specific exercises; at the same time, he/she controls the movements of computer game characters.

***Figure 5**. Gaming sessions for balance training.*

Balance training is performed in the following positions: a) standing on the board and shifting body weight left-right, b) standing and shifting body weight forward-backward, standing with support, d) sitting on the board, e) standing with one foot in front of the other, e) kneeling.

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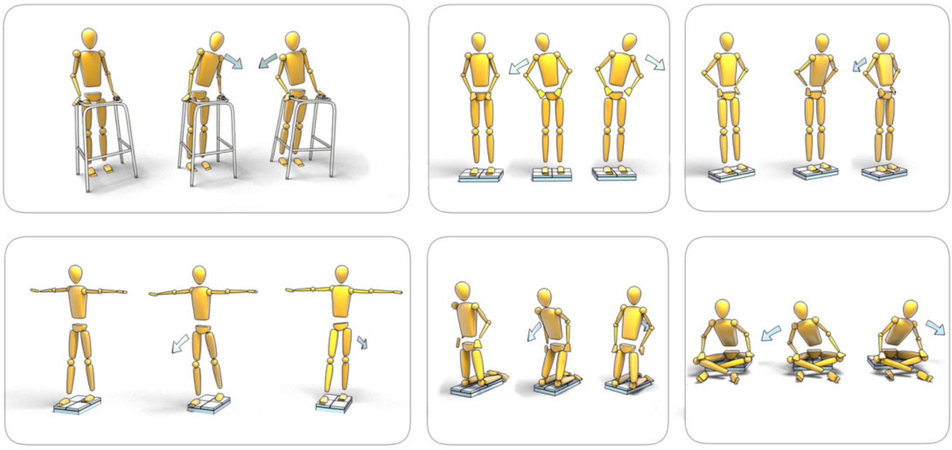
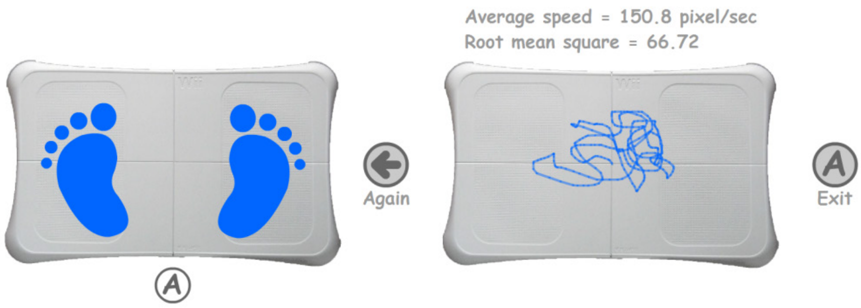
Figure 6. *Training positions for balance exercises.*



Stabilometry as a diagnostic tool measuring equilibrium

Patients with balance disorders can use our system, which includes a special diagnostic tool – a game called "Stabilometry", aimed at evaluating balance disorders. The child should stand still on the balance board for fifteen seconds. Two parameters are calculated: the mean velocity of center of pressure (CoP) displacement and area of CoP displacement.

Figure 7. *The Stabilometry game is a tool for testing equilibrium.*



The mean velocity of CoP displacements indicates how briskly the patient's sway movements are, whereas the area of CoP shows the range of these movements. Higher velocities and larger areas indicate poor balance. The Stabilometry game has not been validated or certified as a clinical diagnostic tool; it is just an additional tool for patients and parents.

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Preliminary system assessment

Preliminary assessment of the Home Rehabilitation Gaming System for balance training was performed on six patients with Cerebral Palsy, who went through daily training sessions for two weeks.

Patients with spastic forms of Cerebral Palsy, aged five to eleven years, cooperative with normal mental development, were selected for the study. All parents and patients were informed and gave their consent for participation. The therapist evaluated each child and drew up relevant training program, indicating recommended games, training positions, and timing. The first two treatment sessions were performed at the rehabilitation center together with the therapist. He registered the patient in the system and trained the child and his parents how to use the system and carry out gaming exercises at home.

For a period of two weeks (twelve sessions), patients conducted daily home training sessions, each lasting thirty minutes. The patients then returned to the rehabilitation center for the second evaluation. They were assessed according to standard evaluation systems, whereas their motor development was classified according to the Gross Motor Function Classification System (GMFCS), the Pediatric Balance Scale, and Stabilometry testing.

The Gross Motor Function Classification System (GMFCS) is a five level classification system that describes the gross motor function of children with Cerebral Palsy. Children at Level I can generally walk without restrictions, but tend to be limited in some of the more advanced motor skills. Children at Level V are generally very limited in their ability to move around even with the use of assistive technology (Palisano et al, 1997).

Table 1. Distribution of patients according to diagnosis, age and GMFCS level.

Patient	Age (years)	Gender (M/F)	Diagnosis	GMFCS level
A	5	M	CP, spastic right-sided hemiplegia	I
B	5	F	CP, spastic right-sided hemiplegia	II
C	7	F	CP, spastic right diplegia	I
D	7	M	CP, spastic right-sided hemiplegia	I
E	11	M	CP, spastic left-sided hemiplegia	I
F	8	F	CP, spastic tetraplegia	III

The Pediatric Balance Scale (PBS) is an instrument with proven reliability and validity, designed to evaluate the child's balance function, including his/her ability to move around in the surrounding environment (Franjoine et al, 2003). It is a modification of Berg's Balance Scale, developed as a balance measure for school-age children with mild to moderate motor impairments. The scale consists of fourteen tasks; each has a scoring scale from 0 to 4 points; the maximum score is 56. The distribution of patients according to age, gender, diagnosis, and GMFCS level is presented in Table 1. The majority of patients were in the five-to-eight-year-old group, predominantly with hemiplegic Cerebral Palsy. Four of them were classified at Level I of motor development; one walked with limitation (Level II), and one girl with spastic tetraplegia was able to walk only with assistance (Level III).

Results and discussion

Assessment results of six patients before and after a two-week home gaming training course are presented in Table 2. The same information is presented as charts in Fig. 8.

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Table 2. Balance testing results of six patients with Cerebral Palsy before and after home game training.

Patient, age	GMFCS level diagnosis,	Before training Balance Scale	Before training CoP Velocity	Before training CoP Area	After training Balance Scale	After training CoP Velocity	After training CoP Area
A, 5 years	Level I, hemiplegia	52	25	8	53	23	8
B, 5 years	Level II, hemiplegia	45	50	8	46	46	7
C, 7 years	Level I, diplegia	47	29	14	48	25	9
D, 7 years	Level I, hemiplegia	48	22	3	50	26	4
E, 11 years	Level I, hemiplegia	49	31	8	51	24	7
F, 8 years	Level III, tetraplegia	7	48 with support	7 with support	7	44 with support	5 with support

Both the table and graphs show data related to Pediatric Balance Scale (A), mean CoP velocity (B), and CoP areas (C) before and after training sessions. An improvement of one or two points on the Pediatric Balance Scale was noted in five cases. Only one eight-year-old girl (F), with low motor development (GMFCS Level III) showed no changes on the scale after the training course.

In most cases, Stabilometry data indicates marked reduction in both average CoP velocity and CoP areas. This is considered positive and indicates that children can maintain a more stable position, whereas their swaying movements become slower and smaller. One patient (girl F) was not able to stand without support, so she was held by one arm during Stabilometry testing. In her case, both CoP velocity and CoP area improved. Only in one case, (a seven-year-old boy (D) with spastic right-sided hemiplegia) was a slight decline in Stabilometry parameters noted, but balance scale performance improved from 48 to 50 points.

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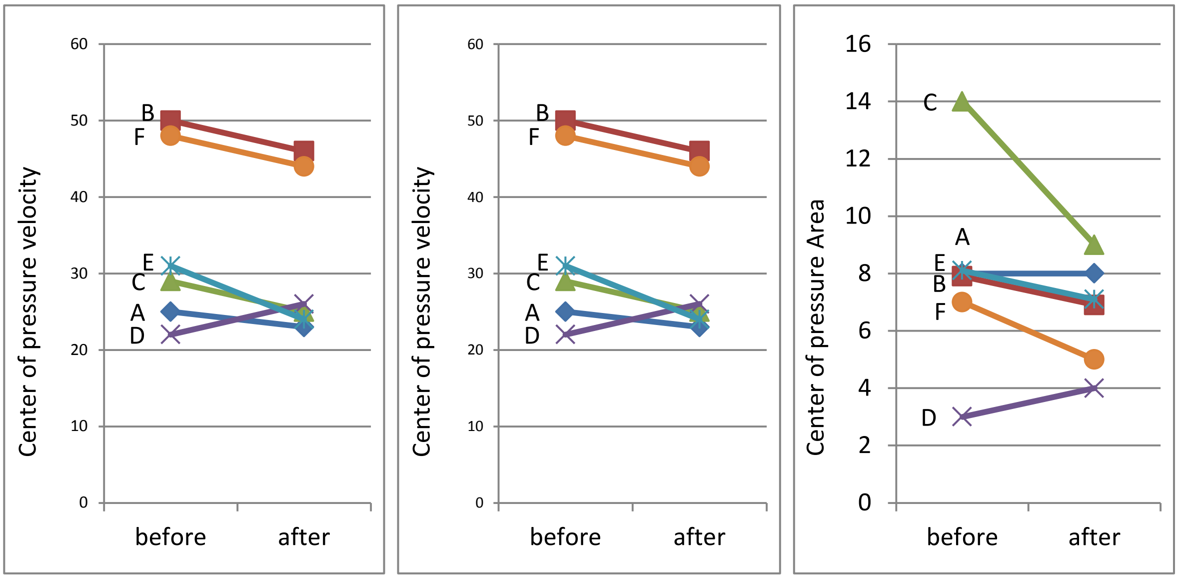
Figure 8. *Graphical representation of balance testing data of six patients with Cerebral Palsy before and after game training courses.*



Study results suggest that home gaming training is beneficial for improving balance function. After the treatment course, the therapist discussed home gaming training with the patients and parents. All the parents and children were satisfied and interested in continuing home training courses.

This is a pilot study; it presents certain shortcomings, and its results can be interpreted only as preliminary. The study was conducted on a small number of patients without referring to a control group or conducting proper statistical analyses. The evaluation of patients was performed by a therapist working together with them, so his assessments may have been biased. Moreover, it is important to determine how balancing skills, obtained during these training sessions, can be adapted to everyday life.

Conclusions

A Home Rehabilitation Gaming System was developed in order to transfer the virtual rehabilitation of patients with motor disorders from clinical to home settings.

Studies indicate the feasibility of this Home Rehabilitation Gaming System to train the patients' balance function. Preliminary results show balance improvement in patients with Cerebral Palsy after home training courses. Further studies are needed to establish medical requirements and evidence.

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A VIRTUAL REALITY EXPOSURE THERAPY FOR PTSD PATIENTS CONTROLLED BY A FUZZY LOGIC SYSTEM

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Abstract: This paper describes the main characteristics of two integrated systems that explore Virtual Reality technology and Fuzzy Logic to support and to control the assessment of people with Post-Traumatic Stress Disorder during the Virtual Reality Exposure Therapy. The integration of different technologies, the development methodology and the test procedures are described throughout the paper.

Keywords: Virtual Reality, Post-Traumatic Stress Disorder, Exposure Therapy, Fuzzy Logic.

Introduction

Nowadays, the increasing production exploring the Virtual Reality technologies is undeniable, particularly in the area of Medical Science. Although the three-dimensional (3-D) virtual environments have been frequently used in the neuropsychological area, the use of intelligent strategies for monitoring the patients' activities is rare. In general, the three-dimensional (3-D) environments open new possibilities to create environments suitable for simulations in the rehabilitation processes of cognitive functions loss caused by traumas and injuries. These environments allow the simulation of real situations integrated with psychological evaluations, proposing tasks "with low risks to the patient". These characteristics stimulate the growing interest in the Virtual Reality Exposure Therapy (VRET) applications.

Many people suffer different traumatic events, but only 10% to 60% of men and 50% of women develop lifelong Posttraumatic Stress Disorder (PTSD) (Masci and Range, 2001). PTSD involves a constant sense of fear generated by the improper consolidation of trauma in the autobiographical memory (Brewin, Dalgleish and Joseph, 1996). Foa and Kozak (1986) argued that some exposure strategies to feared situations are common in psychotherapies for anxiety and that confrontation is an effective treatment for the anxiety disorder. However, for some patients it is difficult to immerse themselves in a scene due to avoidance traumatic symptoms. Thus, the use of new technologies could facilitate the treatment of these patients. In this sense, virtual reality has been used as a tool for exposure and it has achieved positive results in the treatment of several anxiety disorders, including Specific Phobias, Social Phobia, Panic Disorder and PTSD (Meyerbröker and Emmelkamp, 2010).

This paper presents two integrated environments for PTSD treatment: the ARVET (Virtual Environment Exposure to Trauma), a 3-D virtual environment to stimulate the memory of the patient with PTSD and the SAPTEPT (Evaluation System to Patients with Posttraumatic Stress Disorder), which explores the Fuzzy Logic to support the patients evaluation submitted to the ARVET. The ARVET presents some scenes that incorporate stimulus to the emotional processing, allowing an increase or decrease of the emotional answer. The SAPTEPT combines the perceived anxiety, indicated by the patient and the cardiac rate to classify the patient's level of anxiety as mild, moderate or severe. This classification will help the therapist to control the stimulus level provided by the ARVET environment.

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This work is organized into 4 sections. Section 2 describes the main concepts related to the proposed systems; section 3 details the environment and presents the expected interaction results between the systems. Section 4 concludes the work and presents future research directions.

Methodology

This section will present the concepts essential for understanding the software development process: the Post-Traumatic Stress Disorder treatment, the Virtual Reality technology and some aspects about the Fuzzy Logic systems.

PTSD Treatment

PSTD involves a constant sense of fear generated by the improper consolidation of autobiographical memory of the trauma (Brewin, Dalgleish & Joseph, 1996). People with PTSD can not adapt back to their usual life. Thus, a re-reading of the environment they live in will be fundamental to reorganize the experienced situations.

In recent years, different theoretical and practical approaches have been explored to assess and rehabilitate cognitive processes such as visual perception, attention and memory, as well as training the motor skills (Ready, Pollack & Rothbaum, 2006). The Cognitive-Behavioral Therapy (CBT) is considered a good option for Post-traumatic Stress Disorder (PTSD) treatment. In general, it is performed by exploring techniques that include Psycho Education, Cognitive Restructuring Techniques, Anxiety Management, Imaginary Exposure and Live Exposure. Its aim is to break the cycle of symptoms leading to a habituation of stimuli. Moreover, it attempts to develop relaxation skills, enabling the patients' control of their emotional and physiological response in order to decrease their reaction when faced with stressful situations.

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Virtual Reality

The Virtual Reality technology has been widely used in the cognitive stimulation, providing opportunities to offer some situations closer to the real world. Burdea and Coiffet (2003) defines the applications of Virtual Reality as a three-dimensional virtual environments that presents real-time graphics rendered by a computer, in which the user, via body position sensors or user-input devices, controls the viewpoint or the orientation of displayed objects.

In the last years virtual reality exposure therapy (VRET) has become a viable alternative for exposure in vivo, the gold standard for the treatment of anxiety disorders (Meyerbröker and Emmelkamp, 2010). In spite of exposure therapy, some patients find it difficult to imagine themselves in the scene due to avoidance symptoms, leading some of them to abandon treatment. In some studies, dropouts and non-response rates can reach 50% of cases (Schottenbauer, Glass, Arnkoff & Gray, 2008). Therefore, the use of new technologies could smooth the progress of exposure to avoidant patients. In this sense, virtual reality has been used as a tool for exposure and it has achieved positive results for treatment of several anxiety disorders, including Specific Phobias, Social Phobia, Panic Disorder and PTSD (Meyerbröker and Emmelkamp, 2010).

The Virtual Reality Exposure Therapy (VRET) facilitates the emotional engagement of patients with PTSD during exhibitions, outlining the avoidance symptoms, and therefore facilitates the therapist control (Ready, 2006). According to Rothbaum and Mellman (2001), the sense of presence induced by the virtual environment, which is rich in sensory stimuli, helps processing the emotional memories related to trauma. This technological device allows gradual exposure to the feared environment, according to patient needs. In this sense, some experiments have been done worldwide. Torres and Nunes (2011) used three-dimensional virtual environments with characteristics of "Serious Games" to simulate situations aimed at training and therapy. These games allow the simulation of real-world situations, providing training activities that stimulate cognitive functions and

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psychomotor skills. The study conducted by McLay, Wood and Webb-Murphy (2011) evaluates the effectiveness of the VRET in the treatment of PTSD patients on the spot to combat in Iraq. According to these authors, three-dimensional virtual environments can be used to simulate situations aimed at training and therapy. In general, there is no automated control that gives the therapist results from the integration of different biofeedback variables obtained during the VRET. As an alternative, the inclusion of intelligent techniques, as Fuzzy Logic, can help to alleviate this problem by reducing the need of therapist decisions.

Fuzzy Logic

According to Zadeh (Zadeh, 2009) Fuzzy logic adds to bivalent logic an important capability: to reason precisely using imperfect information. Imperfect information is information which in one or more dimensions is imprecise, uncertain, incomplete, unreliable, vague or partially true. Fuzzy Logic uses the formal principles of approximate reasoning and searching to model imprecise reasoning that are usual in the human decisions. It has been a powerful tool, which is able to capture inaccurate information described in natural language and translate them to a qualitative and quantitative form, allowing the position of super categories.

Traditionally, a logical position has two extremes: "true" or "false". However, in fuzzy logic, a premise varies in degree of truth or relevance in the range 0-1, which leads to concepts of partly true or partly false. The control performed by the fuzzy logic mimics behavior-based rules, rather than a control explicitly restricted to deterministic models. The goal of Fuzzy Logic is to generate a logic output from a set of non-precise inputs, noisy, incomplete or even absent ones. According to Braga, Barreto and Machado (1995), "Fuzzy Math is an attempt to bring together the characteristic precision of mathematics and the inherent imprecision of the real world, born from the deep desire to better understand the mental processes of reasoning".

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Fuzzy Logic has been successfully exploited as a tool to support the analysis of tests of three-dimensional environments (3-D), devoted to the teaching and training of medical practices (Santos, Machado, Moraes & Gomes, 2011).

Results

The ARVET and SAPTEPT Systems

Usually, the treatment of a patient with PTSD, provided by the Stress Research Laboratory (Laboratório de Pesquisa Integrada do Estresse LINPES-UFRJ) explores two stimulation strategies: imaginary and live. In imaginary exposure, the patient informs the details of the trauma in a sequential manner at each visit. In this case, the patient is exposed to the reported trauma listening to an audio recorder. In the live exposure the intention is a direct and graduated confrontation to the feared objects or situations.

To support the LINPES practices we developed two applications to help both therapists and patients in the live exposure process. First, we constructed a hierarchy of feared situations to implement a collection of virtual environments to support the exposure to different levels of intensity: the ARVET - Environment Virtual Reality Exposure to Trauma. The ARVET is a collection of virtual reality environments that were built with the possibility of stereoscopic viewing through a large screen and the use of 3-D glasses, which interact with the patient and stimulate them. The tools used to create this environment were: Blender 2.5 (www.blender.org) to model objects in the scene and Unity3D 3.4.2 (unity3d.com) for the animations and interactions. The first prototype simulates some situations involved in urban violence. Figures 1 and 2 show some images of ARVET.

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Figure 1: The ARVET environment: general scenes views

The exposure to virtual environments can generate reactions and perceptions, which are difficult to be assessed jointly by the therapist. Aiming to integrate these data and classify the patient in real time during the VRET process, we developed an application that explores the techniques of Fuzzy Logic - the SAPTEPT - System of the Evaluation of the Patients with Posttraumatic Stress Disorder.

The LINPES researchers distinguish the groups of Psychometric and Psycho-physiological variables, whose values are collected during evaluations. Psychometric scales are established by filling in forms of self-report and Psycho-physiological data are obtained through the Biopac (Physiological data acquisition system).

Figure 2: An example of a scene of an accident: a person was hit by a bus

The scale used to measure the patient level of anxiety is the SUDS - Subjective Units of Disturbance Scale that assesses the degree of anxiety during the trauma stimulation. The SUDS is a range of integer values

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between 0 and 10 that measures the intensity of disturbance or distress experienced by an individual when subjected to trauma. For example, the individual perceives their level of anxiety at the time of exposure to the trauma, ranging from "no anxiety" to "high anxiety".

A meta-analysis conducted by Pole (2007) identified the Heart Rate as a Psycho-physiological group variable that changes when PTSD patients are exposed to a traumatic stimulus. Thus, the heart rate level confirms or not, the patient's anxiety. In this case, we consider the level of anxiety reported by the patient and the heart rate.

The Fuzzy Logic used in SAPTEPT captures inaccurate information, described them in natural language and converts them in qualitative information. The Fuzzy Logic can control the behavior of a system by changing the inputs according to a set of inference rules. These behavior-based rules model the system operations. The method, from the viewpoint of Fuzzy Logic, allows us to recognize patterns of anxiety gradual scale (Mild, Moderate, and Severe) in real-time measurements, when the psychometric scales (anxiety) and psycho-physiological (heart rate) are performed (Figure 3). Pattern recognition is one of the oldest and most obvious applications in the area of Fuzzy Theory.

This system classifies the patient’s degree of anxiety while they are navigating in the ARVET. It indicates the difficult level changes that must be performed in the ARVET scenario. All tasks, scenes and the patient classification in the Fuzzy System were proposed by a group of psychologists, which are responsible to test these systems with their patients.

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Table1. This table describes the fuzzy inference results from the heart rate X anxiety variables. For example, when the heart rate is moderate and the patient say that his level of anxiety is mild, the system will classify that the patient level is moderate.

	Heart Rate		
Anxiety level	Mild heart rate	Moderate heart rate	Severe heart rate
Mild	*MILD*	*MODERATE*	*SEVERE*
Moderate	*MODERATE*	*MODERATE*	*SEVERE*
Severe	*MILD*	*SEVERE*	*SEVERE*

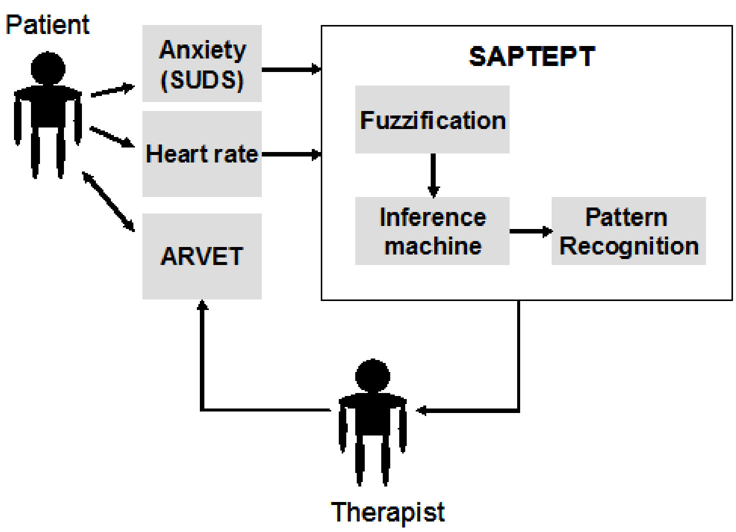
The SAPTEPT was developed in Python programming language and shows the classification of the patient every five minutes from the start of the evaluation. The results form the SAPTEPT system must be monitored by a therapist.

After the patient is classified in a new level, the therapist will ask him to open a door and enter in a new scene (Figure 4) that will present situations according to the patient classification.

Figure 4. The doors where the patient must enter to change the level of stimulation

A pipeline of the system use is presented in Figure 5.

Figure 5. The pipeline of the system use.



Discussions

Aiming at analyzing some aspects of the prototype, we developed an evaluation experiment with two psychologists. This evaluation considered some usability aspects as: navigation facility; learning facility; response time; realism of scenes; pleasantness of the scenes; adequacy of objects in the tasks and matching colours.

The initial results of this experiment indicated that the 3-D environment has a high level of usability, but some aspects must be changed: some colors, some architectural details and the speed of buses and cars. At the other side, the Fuzzy system must have its interface slightly modified in order to facilitate responses from users about their anxiety level.

After those steps, the system will be used by a group of people with Posttraumatic Stress Disorder to measure its efficacy in control the level of tasks according to the patient evolution.

The prototype can be used in the first instance for cases of patients diagnosed with PTSD due to hits or car accidents (very common in large urban centers).

Conclusions

In Brazil, there is a growing interest in the Virtual Reality technology to support health care procedures. In this sense, we need new software and new treatment strategies, where patients may have unrestricted access to the exercises with therapists precisely monitoring the results. Thus, in this case, the virtual environment must have some mechanisms to control user navigation and generate automatic reports to the therapist.

However, the development of such software depends on the integration of different technologies and expertise. In this context the Fuzzy Logic offers wide possibilities to control the user answers and support the therapist decisions.

This paper presented some results of a project that has two objectives. The first one is associated with the technical questions related to the intelligent strategies to support decisions and the second deals the integration of the intelligent modules with specific virtual three-dimensional environments. The next step of this research is to integrate the SAPTEPT with the ARVET.

Some therapists (psychologists) tested the system and proposed some changes that were considered in a new version of the system. The system is currently being tested with a group of people with PSTD associated to car accidents.

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CAMERA-BASED SOFTWARE IN REHABILITATION/THERAPY INTERVENTION

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Abstract: Use of an affordable, easily adaptable, 'non-specific camera-based software' that is rarely used in the field of rehabilitation is reported in a study with 91 participants over the duration of six workshop sessions. 'Non-specific camera-based software' refers to software that is not dependent on specific hardware. Adaptable means that human tracking and created artefact interaction in the camera field of view is relatively easily changed as one desires via a user-friendly GUI. The significance of having both available for contemporary intervention is argued. Conclusions are that the mature, robust, and accessible software *EyeCon* is a potent and significant user-friendly tool in the field of rehabilitation/therapy and warrants wider exploration.

Keywords: Rehabilitation; Healthcare; ICT; Sensing; Cameras

Introduction

A focus of this contribution is applied camera sensing via software requiring non-specific hardware as investigated in a mature body of research titled SoundScapes. In this work, a key focus is on ICT ease-of-use to support end-user/carer/staff/therapist operation via an accessible user-friendly GUI.

SoundScapes is a body of research built upon the author's domestic situation that offered direct relationships to family members with profound disability. In line with this, the research was conceived to explore needs for people with impairment. Investigation of the potentials of alternative intervention strategies using various sensors led to the creation of a bespoke infrared non-worn sensor-based biofeedback system. The method focused on using plasticity of digital media (ICT) to achieve alternate channelling of multimedia feedback stimuli to bypass usual routings. Thus, to affect damaged sensing mechanisms through complementary strategies according to user profile. For example, in the case of acquired brain injured patients (stroke) where sonic feedback of balance or limb movement supplemented proprioceptive and kinaesthetic sensing.

Early bespoke systems were explored for use in treatment/training/leisure involving natural interaction via residual functional movement for disabled people. The wireless (non-worn sensors) system enabled non-invasive interaction (i.e. gesture-control) of digital multimedia. A prototype system was created for disabled people to improve engagement and participation in treatment/training sessions that were fun and enjoyable yet still rewarding and beneficial to the therapist's goal for development. Game playing and creative expression (making music, digitally painting, robotic control etc.) through gesture control was a catalyst of the concept, thus the interchange between the fields of disability, art and games has been active, fruitful and a rich thread to the work. A patented product evolved from the research prototype (Brooks & Sorensen, 2005). The fact that the invention was designed and realised to target disability differentiates SoundScapes from other systems conceived for other purposes, e.g. game playing, dance, music, and subsequently adopted to be used in the field.

Ultrasonic (linear profile) and camera (planar)-based technologies were subsequently investigated alongside the 3D profile IR sensors, both individually and in combinations, due to their different capture profiles. Thus, via an evolved 'mix-n-match' methodology, another can balance limitations of one technology so that volumetric/3D, linear, and planar/field-of-view could be selected and combined as appropriate. This research posits how unencumbered gesture-control of multimedia in rehabilitation intervention is an effective strategy. It also posits how the SoundScapes 'mix-n-match' combining of sensor technology profiles predates the arrival of contemporary video game control devices that exhibit multi-sensors in a single unit (e.g. Nintendo Wii, Microsoft Kinect).

SoundScapes investigations highlight how data sensing personalization (human control input) and responsive content (multimedia feedback) tailoring by staff/personnel with limited training requires a suitable interface. Such tailoring opportunities are unattainable to traditional facilitators because a suitable interface is missing from many systems. Thus, intervention optimisation is either restricted to those with having technical comprehension or a programmer needs to be employed. The goal of this contribution is to share a software solution titled EyeCon that aligns with such requirements, yet originated outside of rehabilitation (in dance performance). Considering its usability in the field, it is surprisingly rarely explored as an immediately useable software tool. Before introducing the software, a unique technique for intervention with invisible technologies is presented. It is based on the neurological ability of the brain to evoke the unconscious search impulse motor action of reafferentation.

'Reafferentation intervention' is a technique developed by the author in SoundScapes. The technique involves, during a session intervention, manipulating invisible digital artefacts that can be envisioned as points in space. The points are data-mapped to trigger digital content when 'touched' by a participant. The feedback content stimulates the participant's interactions according to a therapist's goal such that a repeated 'touching' of the invisible point in space results in achievement. Once the achievement is attained, the 'Reafferentation intervention' manipulation involves moving the invisible artefact ever so slightly away from the participant without them being aware of the change (usually an increment in pre-sets by the facilitator). An example goal can be of extending a participant's movement as the reafferentation pipeline evokes the brain afferent response to a non-location feedback to signal efferent mechanisms into search mode. Once the new location is 'touched' and feedback achieved such that the brain's afferent stimulus is satisfied the new location becomes the efferent 'memory'. This human afferent efferent neural feedback loop closure is central to the on-going research. The term 'manipulation' is used as the

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participant is tricked by the technique to not be aware of the incremental extending (see Virtual Interactive Space detailing intervention method in Brooks, 1999).

Investigations reported on how such unencumbered interaction with interesting feedback to exercise was found to be a preference offering increased engagement and participation in sessions resulting in improved outcomes that align with traditional goals from rehabilitation and therapy.

The selected technical pipeline used the MIDI protocol and Max object-oriented programming software for mapping the various sensor data to the multimedia content via created simple interfaces. However, a weakness with the original system became apparent when the author was commissioned to produce for third-party use across a network of institutes (i.e. the author was not involved in the actual intervention). Evaluation sessions with therapists of the use of the system highlighted that even with a simple interface created for therapists and staff, extensive training was required to ensure third-party comprehension and part-optimal application. Thus, camera-based technologies where a therapist could visualise the sensing space via the camera field of view was integrated. The outcome of the integration was significant and led to amalgamation of the EyeCon software as illustrated in the next section. Additionally, the adoption in the field of such sensing technologies aligned with suitable methods (as exemplified previously in this text) has been wide with positive outcome and developments and this is also presented next including related work.

Methodology: camera-based sensing systems

The section introduces integration of camera-based sensing in rehabilitation research. It illustrates how adoption of 'alternative' camera-based systems in rehabilitation increased at the turn of the century through two examples. The studies are selected to illustrate how the need for access to the core attributes of a system to enable adaption to a specific user/patient and their progress was not made available by the commercial product gatekeepers.

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More recently, open source initiatives enable such access and sharing of information such that advances are increasing in camera-based solutions.

Kizony et al. (2002) reports on the use of a camera-based game system in rehabilitation that evolved from technology originally conceived as a tool for interactive audio-visuals performance. A follow-up study concluded that the system tool, VividGroup's Mandala Gesture Extreme (GX), was expensive and requiring an elaborat0e setup (Weiss et al. 2004). In this study Sony's PlayStation II's EyeToy®, a more affordable commercial camera-based game system, not requiring such a set-up, was favourably compared. However, the EyeToy "closed architecture", preventing system parameter access, was a negative aspect.

Brooks & Petersson (2005), similarly reported negativity regarding access to the EyeToy in a study at two hospitals in Sweden and Denmark with 18 children (in 20 game-playing sessions each) and a control of non-participants with facilitators being two play therapists and three doctors.

Both the above-mentioned systems require specific hardware, mapping and content. Inability to access the data clearly limited the potentials for any system's ability to be adapted to an individual's need. Both VividGroup (now GestreTek) and Sony were approached about allowing access for rehabilitation adaptation. Both companies, from the highest level, responded negatively and no access was permitted for the research.

Around the turn of the century, the author researched with a camera-based software that originated from Genoa University. The EyesWeb software enabled object oriented programming of patches to enable desired results. This is introduced in the next section. However, again the end-user interface level was not ideal for techno-phobic therapists in their daily training sessions. Shortly afterwards, video game companies began producing alternative gesture-based controllers featuring multiple sensing technologies. All included one or more cameras. The Nintendo Wii was launched in 2006 and was the first such apparatus where the sensing data was accessible. In 2010, Microsoft followed with their Kinect device for Xbox that supported movement, voice, and gesture recognition technology. Whilst

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the Wii was accessible via third party software, Microsoft supported third-party developers by releasing a stand alone version of Kinect and a designated driver and software development kit (SDK) for use with Windows 7 on June 16, 2011. This SDK allowed access for developers to write Kinect applications in C++/CLI, C#, or Visual Basic.NET. New opportunities in rehabilitation became apparent through the access; however, the end-user interface was still a problem in order to fully realise potential of professional rehabilitation therapists' uptake. Recent research by the author has been to address and alleviate this problem.

This contribution makes the case for user-friendly software that is mature, robust, and affordable. The software enables any standard PC connectable camera to capture data where the field of view is easily accessible for parameter change via a user-friendly interface that allows mappings to content that can similarly be accessed. In this way, flexible tailoring of a system feed forward and feedback can match a subjects' - and therapists' - current requirement as well as offering incremental challenges to match and optimally stimulate progression in treatment programmes. The next section introduces the EyeCon software that has an interface that approaches what may be approved as user-friendly by the end-user.

Camera-based sensing systems in SoundScapes

Camera sensing as used in SoundScapes has involved a number of techniques toward optimising the intervention and archiving for analysis. Design of sessions plan for familiar surroundings for the subject and minimal change (e.g. no Chroma screen is required as backdrop). The software importantly enables (a) the tracking of the human body in the field-of-view without any worn reflectors etc., (b) the assignment of dynamic artefacts in the field-of-view that can generate signals when invisibly 'touched' (cross referenced by pixel location), and (c) signals can be easily mapped to open/accessible multimedia (internal to the computer or external). This (a) differs from traditional methods of body tracking where reflective body markers are located in the field-of-view of single or multiple dedicated high-specification cameras (e.g. Vicon, Qualasis, Xsens…). The use of marker-based motion

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capture systems is problematic with certain patients due to preparation time. The assignment of dynamic artefacts (b) is important to enable reafferentation intervention, alongside (c) to ensure flexibility and personalisation to ensure the system adaptive to a patient/user profile and therapist goal.

Originating in Italy for interactive performance, The EyesWeb visual programming language software (Camurri et al., 2000) has been used in SoundScapes and other rehabilitation studies (e.g. Williams et al. 2006) and operates with a standard camera linked to a PC. Both human tracking (including basic skeletal) and artefact assignment/mapping is used in EyesWeb without Chroma screen; it can also map the signals to multimedia and full access is available. However, there is not a user-friendly GUI. Thus, the focus of this contribution is not EyesWeb but rather the aim is to introduce another system that was created in Germany titled EyeCon that enables similar yet alternative and possibly less complex opportunities as EyesWeb. Surprisingly, this software has rarely been used in rehabilitation intervention outside of SoundScapes until recently. As EyesWeb, it is created for interactive performance and dance; however the body tracking is not skeletal. One main difference in these systems is the user-friendly graphical user interface of EyeCon that is not present in EyesWeb. This interface makes EyeCon an easily learnt adaptable capture and mapping system to content that is accessible to be manipulated. Illustrations from examples of use within the SoundScapes body of research are given from a study involving 91 participants in six workshop sessions in Portugal from 2007.

The eyecon software

The EyeCon software was originally conceived for dance and interactive performance. Petersson and Brooks (2007) report on the use of EyeCon as the core technology around which six workshops focus upon alternative rehabilitation intervention. These were designed for accessible creative and playful participation involving ninety-one attendees of differing abilities. Sixty-one attendees were disabled. Thirty-nine had profound and multiple impairments; an additional thirty were from music teacher higher education. Positive outcomes are reported with the goal of the sessions achieved.

Figure 1. EyeCon's camera field of view showing created artefacts (green). The female dancer uses her hand to trigger media assigned to line artefact 'A5'. Source: © EyeCon.

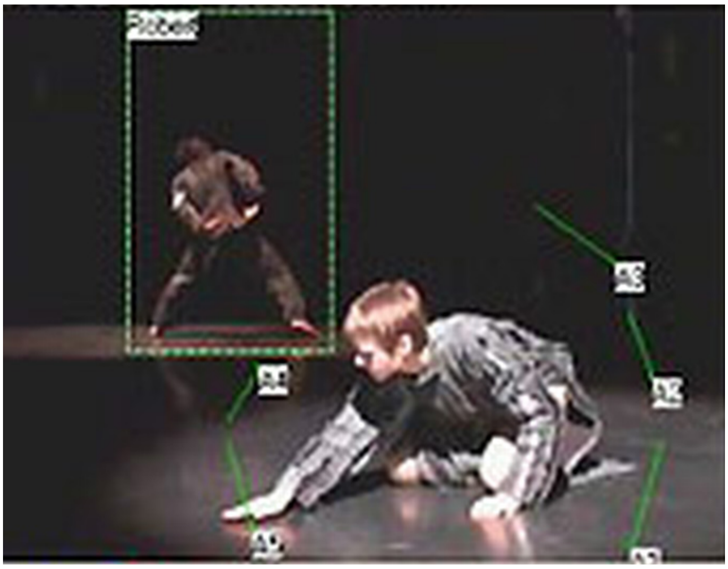
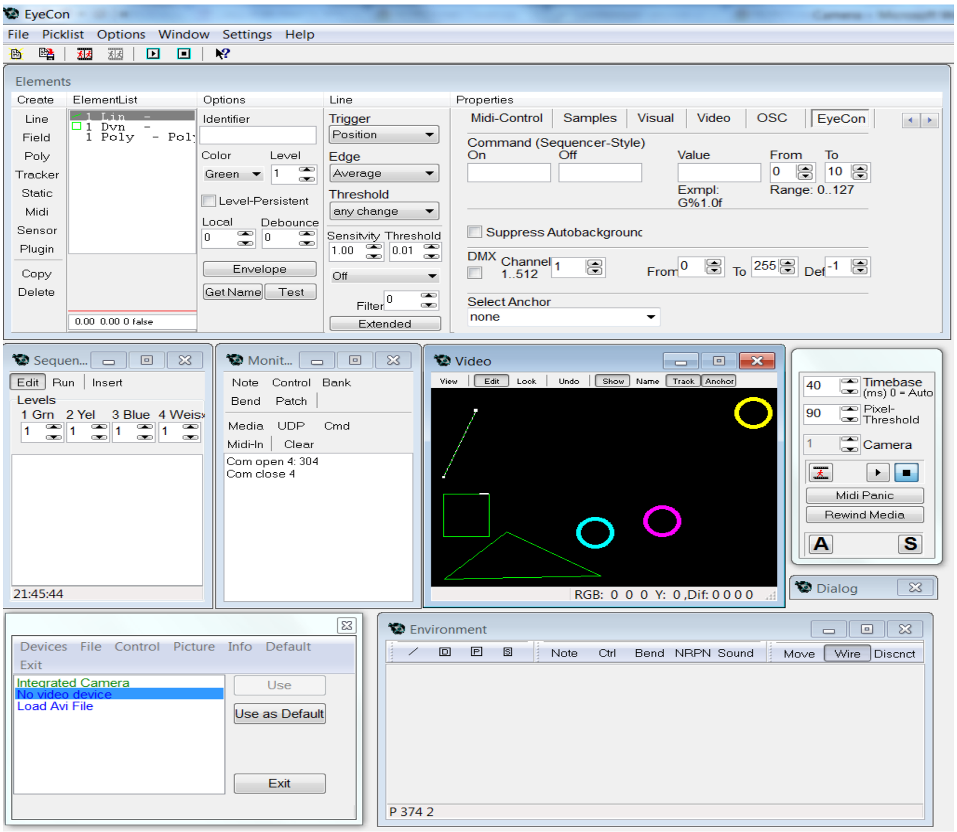


Figure 2. EyeCon interface window in test mode. Source: © EyeCon.



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The EyeCon software offers access to digital content via a capture and mapping user-friendly interface. The interface uses the camera field-of-view (FOV) as a canvas where lines, zones and other dynamic artifacts can be drawn by the mouse. The artifacts are mapped via the interface to selectable content. Figure 1 illustrates the human interaction with the created artifacts (green lines). By a participant interrupting the green lines – based on pixel gradient – the assigned software mapping action results.

Figure 2 illustrates the interface window showing the facility to test mappings with moving circles that activate the media when overlapping the artefacts (the green line, square and triangle). This is used when developing and no participant available.

Each configuration can be saved so a next session can begin where the previous ended to work toward progressive participant micro development.

Outputs include: Internal or External MIDI; Direct X systems (Audio Sample player); Windows Media Player (AVI Video); Control of Screen Canvas Effects; OSC message output via Ethernet; all MIDI-standard commands (pitch-bend, volume, etc.).

Figure 3 and 4 illustrate the use of EyeCon in workshops with disabled participants and music therapy students. Interruption of the dynamic areas triggered sounds while motion in the camera's FOV was processed to unmask mirrored digital paths that revealed images of famous football stars. The design was motivating for the participants who supported each other. Previously, a similar workshop set up was hosted at the National Institute for Design, Ahmedabad, India, where cricket star images were used to motivate the participants. Such workshops are considered exemplifying the plasticity of digital media where human performance plasticity is targeted.

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Figure 3. EyeCon software tracks a woman out of her wheelchair who is motivated to move to open a digital mask that originally hid the famous Portuguese soccer star Luis Figo. Source: SoundScapes©.

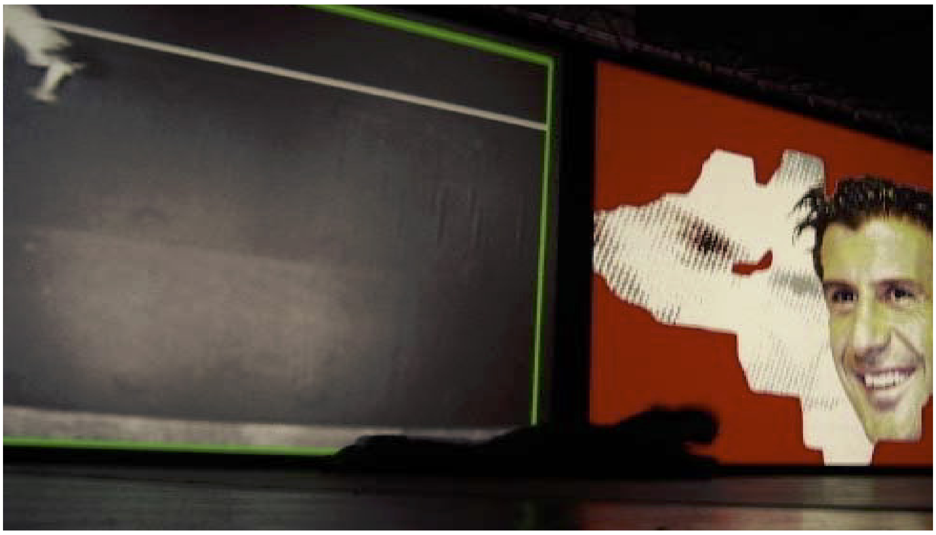

Figure 4. EyeCon (left screen) plus Eyesweb (right screen) software (split camera feed) - Dynamic zones (rectangles) are mapped to music loops and digital painting where the gesture dynamics determine colours and images. SoundScapes©

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Results / discussion

SoundScapes investigates behaviour aspects of interaction with a virtual environment where unencumbered gesture is empowered to control aspects of the computer-generated digital content that constitutes that environment. The gestures that are used to control the environment content are motivated by the interactions and provide data on the user's physical function that in any treatment/training that involves movement can provide significant information to evaluate end-user progress from intervention. An outcome from the SoundScapes research is how such software can contribute to the field by evolving test batteries based upon digital 'measures'. New test batteries using camera-based software such as EyeCon can give quantifiable results of user-progress at pixel level. The complete access to parameter change, both input sourcing and content mapping, is desired for optimal tailoring and this is possible with EyeCon so that incremental challenges of interaction can be adapted according to micro development progress. The context-specific content is used to motivate engagement and participation. In figure 3 from the 2007 workshops, a soccer luminary is used to motivate in the Portuguese workshop due to the high interest in the national sport. The same SoundScapes set up using EyeCon in 2003 was created with Indian cricket players as a part of a two-week workshop at the National Institute of Design (NID) in Ahmedabad when the author was an invited lecturer. This use of famous sports personality's images is selected according to the workshop's host country. User-generated content (UGC) for user real-time manipulation is a strategy also an option for increasing user engagement, motivation, and participation. Figure 4 illustrates EyeCon artefacts and crowd interactions.

Camera-based system stability can be disrupted when image manipulations are involved due to the change in luminosity affecting pixel threshold. The Eyescon software offers lumen threshold adjustment. A technique used in the workshops was infrared motion sensors featuring an interface technology utilising light beyond that which is visible to the human eye . This is to create independence of visible light.

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Some light-change sources such as projectors, moving headlights, or Hydrargyrum Medium-Arc Iodide (commonly known as Arc or HMI lamps/lights) do not emit infrared . Thus, the camera can be made totally blind to those light sources. In line with this set up, the workshops were conducted in minimal light conditions for participants to focus on the manipulated content.

The social aspects evoked within SoundScapes are also of importance as evident in the Portuguese workshops example (also in the India workshops). This is exemplified by how the woman lying on the mat in figure 3 (shadow profile) asked to get out of her wheelchair to participate. She was supported by her colleagues in her progress of the task to uncover who the soccer star was. The aforementioned video exemplifies further with an autistic user.

Conclusions

This contribution has an aim to introduce rarely used camera-based software to encourage carers and therapists who may be techno-phobic of ICT supported interventions for rehabilitations. The EyeCon GUI (Graphical User Interface) that is the operational gateway to create invisible artefacts that can be triggered and controlled is a user-friendly entity that encourages exploration. In SoundScapes studies across disabilities, age, and situation, the EyeCon software has shown itself to be a potent tool that can offer significant opportunities and benefits for intervention sessions. This is due to the fact that both sensing and mapping to content is accessible.

It is evident from increased use in researches in the field that camera-based software offers many opportunities in the field of disability and is a significant tool for rehabilitation/therapy intervention. Such software, whether specifically created or adapted for the purpose, is increasingly becoming available through research, open-source and other communities.

The introduction of camera-based game systems, such as cited in this report, support intervention initiatives and are increasingly being adopted in the field of rehabilitation. The biggest impact in this respect is the camera-

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based Kinect hardware peripheral for the Microsoft X-box that, via the demand for data access, has resulted in a stand-alone (non-X-box) PC version of the hardware alongside software drivers and a designated SDK to enable creative programmers' open access to raw sensor data. More recent are the introduction of related devices such as the Leap Motion[1] and 3gear[2] systems that track hands and fingers. Such devices alongside worn apparatus that enable head tracking and immersion in the computer-generated environment such as the Oculus Rift Head Mounted Display (HMD), which again is affordable and open source for content adaptation, complement targeted user-experiences that can advance rehabilitation and therapy. Other systems that enable tactile/haptic, olfactory and other feedback are also becoming increasingly available toward eventual integration as a single system. Additionally, it is seen that advances are being made in Virtual Walking devices for games, such as the Virtuix Omni[3], which could potentially be used in rehabilitation as a gait or balance aid.

SoundScapes attempts to trial as many devices and software as possible where possibilities are envisioned for intervention so as to ascertain pros and cons of each system and to explore mixing-n-matching opportunities to optimize usage.

Strategies of adopting devices that may already be in the end-user's home (such as game gesture controllers, later HMDs) also opens up home-based training and the use of the internet to communicate results to a therapist in line with telerehabilitation – see Brooks (2004). In line with this is the importance of end-user access to ensure uptake and compliance so that ease of use if a key design prerequisite. The future is exciting.

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[1] www.**leapmotion**.com
[2] www.**threegear**.com
[3] www.virtuix.com

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