

# **HUMANICS 1 – a feasibility study to create a home internet based telehealth product to supplement acquired brain injury therapy**

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## **ABSTRACT**

The goal to produce a unique, cost effective, and user-friendly computer based telehealth system product which had longevity and the ability to be integrated modularly into a future internet-based health care communication provision was conceptualised as an aid to home-based self-training. This through motivated creativity with the manipulation of multimedia. The system was to be a supplementary tool for therapists. The targeted group was initially to be those with acquired brain injury. This paper details phase 1 of the product feasibility testing.

## **1. INTRODUCTION**

Acquired brain injury rehabilitation entails a long and enduring process towards training the individual to a realisation of potentials so as to be able to live a life with optimal quality following injury. Training often involves travel to a clinic which involves certain stressful situations, economic considerations as well as environmental consequences. A system design where private individuals could be motivated to train at home and utilizing the internet send their progress information to the clinic therapist for management was novel and judicious. Furthermore the all essential support from family members could provide added motivation as all are capable of ‘playing’ together with the system in the home setting. The question was asked however whether a generic system could be created that would be ‘user-friendly’ and efficient across age groups, ability groups and have continued worth over novelty value as is often seen in similar ‘tools’. This paper chronicles the first phase of the research which was established as a feasibility study to ascertain if the target group could benefit from such a product and to receive their input. In so doing it lays out the foundation and philosophies involved.

## **2. BACKGROUND**

At the ‘Year of the Brain’ conference in Aalborg, Denmark, the author presented his ‘SoundScapes’ body of work (Brooks 2003). Prominent figures from two of the leading Centres for Rehabilitation of Brain Injury were in the audience and, understanding the potentials inherent in the concept, they approached the author which resulted in trial sessions being initiated with physiotherapists and acquired brain injured patients. The sessions led to further collaborations and presentations including one where the author won the top European prize at the BAM (Brokerage Applied Multimedia) event hosted by the Eureka organisation in Stockholm, Sweden. The presentation was of his evolving research within the field of special needs and his design of the proposed telehealth system product which is the subject of this paper. Subsequently in a collaborative effort with the same team from the Centre for Rehabilitation of Brain Injury in Copenhagen the project which is covered by this paper was initiated which resulted in a Danish government funding of the study.

The Humanics study that this paper refers to was covered by non-disclosure agreements under the Danish government product development contract until recently (2004) whereupon written clearance was given by the CRBI enabling the author to publish on the project.

### **3. CENTRE FOR REHABILITATION OF BRAIN INJURY (CRBI)**

The CRBI was established in Copenhagen, Denmark in 1985 for the rehabilitation of acquired brain injury through holistic & individual treatment with a main focus on return to work and/or improved quality of life. Today, in 2004, it is a self contained entity based at Copenhagen University following in 1993 being awarded the Special Institute Status and accordingly it initiates training, research and education programs. It is one of the top European Centres and the team consisting of Psychologists, Physiotherapists, Neurologists and Speech Therapists is highly respected in the field. The aim of CRBI is stated as:

*Integration through:-*

*'Training and awareness of psychological & physical deficits & strengths' and 'Insight & Compensation techniques'*

### **4. PROJECT CONCEPT**

Most people joyously appreciate moving or dancing to music. *Creating* music and images with body movement alone adds a new and different dimension to such joy. Physical rehabilitation after sustained brain injury is often an enduring and cumbersome task to the patient, who is only encouraged if a feeling of progression is present. If productive creativity could supplement such feelings of progression, or perhaps *be the progression*, then physical rehabilitation might be a different, more exiting and inspiring part of life after sustained brain injury. Since creativity, challenge/success and motivation are at the core of the original system, the work also focuses on these (all too often ignored) aspects of rehabilitation. In the same perspective this focus might affect the creativity and motivation with which the patient meets every-day tasks. The aim of the project was to create a home based untraditional IT-system supporting these goals and which would work as a supplement to traditional physiotherapeutic training. This is illustrated in figure 1 where the patient is at the top tested in the clinic and the system calibrated with his specific expected progress data. He takes the system home and trains with the family support and without the stress and costs involved of having to report physically to the clinic daily or weekly. The progress of his home training is sent automatically via the internet to the clinic for monitoring, fine tuning and feedback via web cam & mails.

### **5. CREATIVITY & MOTIVATION**

Creativity seems to defy definition and along with motivation is often overlooked in rehabilitation. This means it is often dismissed as a parameter when trying to define measurable goals in rehabilitation (and in many other areas). Yet we know that the feeling of creating something unique or personal is often a source of satisfaction. Thus creativity may well be a source for motivation. In rehabilitation it is clearly apparent, that focusing on improvement promotes motivation for the patient to exercise. With use of feedback to movement of the whole body as well as parts thereof, the project used concepts of music and dance as well as games, tasks and challenges to keep patient's motivation high when 'working out.' A main idea relative to the earlier research by the author is to be able to "hear the way you move" towards an improved proprioception.

### **6. MOTION CAPTURE**

'Motion capture' or 'motion tracking' is about capturing human movement and translating it into knowledge about movement efficiency. It is used for example in sports, film animation and rehabilitation. Several different approaches have been used ranging from expensive multi-tracking camera systems (Vicon, Qualisys, SIMI) to more low cost "wearable systems" (DIEM, Troika) connecting to the computer through cables which are encumbering and impractical for rehabilitation. Such camera systems involve 'expert knowledge and training' for operation and typically are located at institutes which are funded accordingly.

The capture system for the Humanics project was conceptualised as a cost-effective sensor/camera system. Parallel studies with camera systems proved fruitful and it seems pertinent to state that the SoundScapes system that was used for this feasibility study utilising only sensors is now a non-tangible system including cameras and sensors as proposed in the author's original Humanics system design.

### **7. SOUNDSCAPES SYSTEM**

SoundScapes is a system which consists of a variety of non-wearable movement sensors which register motion. The movement information is routed to a computer, which then transforms the data into sound,

image and coloured light patterns. Thus, the participants receive an immediate feedback on their movements. In this way, the participants have the opportunity to see/hear their pattern of movement and to see/hear which parts of the body they are moving/not moving. Such a feedback can be of singular importance to for instance people with acquired brain injuries with hemipareses with or without neglect. The participants themselves have the opportunity to choose which kinds of feedback they want.

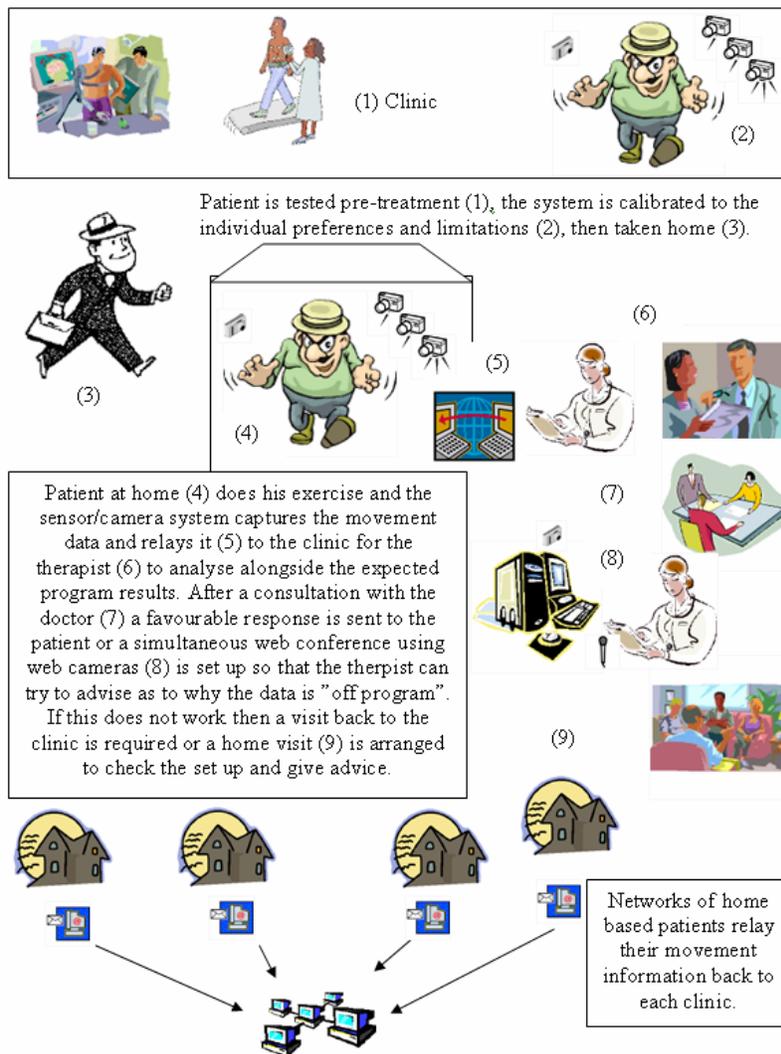


Figure 1. Humanics telehealth system

## 8. RESEARCH OBJECTIVES

The following issues were addressed through the study with the system:

- Does the system give patients with acquired brain injury with physical injuries, an increased physical level of activity and function?
- Does the system have the potential to become a relevant and novel system, and can it increase motivation for physical rehabilitation?
- If the Humanics System is implemented in the patients' home: Is there a potential for increased training efficiency or other benefits by live www-connections between patient and physiotherapist?
- Is implementation of the System as training measurer in private homes a viable prospect?

- When training in the system: Is a more free style of training (e.g. no specific physiotherapeutic exercise or goal) preferable to a more restricted type of training (e.g. specific physiotherapeutic measures and aims, comparing achieved goals, etc.) or vice versa?
- Can results from the system be shown to correlate with functional change measured by traditional physiotherapeutic tests? And if it can; which functions will it be possible/desirable to measure?
- Working with the system: Are creative and motivational aspects of specific activities outside the training sessions affected?

## 9. METHOD (Phase 1)

The single-case feasibility study included 5 adult patients<sup>i</sup> selected among patients formerly enrolled in the CRBI rehabilitation program<sup>ii</sup>. Training with the baseline SoundScapes system was over one 3-week period. During the training period a rehabilitation physiotherapist collaborated with the author to train and introduce all patients in one-hour sessions. Over the three weeks a maximum attendance was 11. Each session consisted of activities for the patients needs. The entire session of phase 1 utilized the SoundScapes system.

All patients are individually tested following the schedule below:

- At inclusion: User Interface Questionnaire / Prior experience with computers (see appendix 3).
- Immediately before and after the training period. Physiotherapeutic testing including tests of general fitness, balance, level of activity, and quality of movement (see appendix 1). Psychological testing of creativity and motivation (see appendix 2).
- At every training session: Multiple camera video recordings<sup>iii</sup> and audio comments taped by the physiotherapist were collected.
- Where possible results from tests carried out immediately after the traditional rehabilitation program at CRBI are used as reference points.

## 10. PATIENT SELECTION FOR HUMANICS

As mentioned potential participants were selected from a group of patients formerly enrolled in the traditional post-acute rehabilitation program at the CRBI. At a very general level patients enrolled in this program are typically ½-3 years post-injury and are able to handle most essential ADL at a reasonable level. A total of 51 adults, 26 male and 25 female patients with acquired brain injury (stroke or trauma) aged 24-62 yrs. were selected as potential participants. Exclusion criteria were inherent cerebral dysfunction, any history of psychiatric disease and substance abuse. All participants continue to have physical impairment following their injury (this means that reduced functions of one or more body parts are observed by means of common clinical, neurological assessment). Time post-injury for most patients was 2-7 years having participated in the rehabilitation program 0-4 years ago. Since the patients of the Centre (CRBI) are among the best functioning 30 per cent of all Danish people with brain injuries, many of them were occupied in jobs in some measure. Measures were taken to create homogenous groups of patients in relation to age, gender and localisation / degree of injury. Focus has been put on the largest possible variation of physical after-effects from the injury/the illness.

## 11. SESSIONS

### 11.1 Set up

The SoundScapes system was set up as a makeshift laboratory in a large room in the University of Copenhagen adjacent to CRBI. The equipment was primarily - a PC, a three headed infrared volumetric sensor array (author prototype); an ultrasonic linear sensor (*Soundbeam*); three intelligent robotic light devices; and peripheral interfaces and cabling to source, route and map movement signals into the computer workstation. The protocol of MIDI (Musical Instrument Digital Interface) was the core language.

### 11.2 Training

An intense three week period was scheduled and the participants attended sessions of one hour duration. Some were not able to attend all of the sessions and the maximum attended possible was 11 times. The most was 10 times with the average of the others coming 5 times over the three week period. The exercises were inductively designed relative to each person's damage and preference for limb/functional training. Many of

the improvised exercises proved of great worth and were sustained throughout the period (see 11.3 below.) All were trained with the use of the system giving them an auditive feedback relative to their balance. This was often with the eyes closed which was a problem for many of them and support was required, however they were very positive about this although it was difficult for them. Often they would initiate a sequence of movements that they had previously been instructed to perform or had self-created to help in training. The role of the system in such instances was to give an auditive and/or visual feedback relative to the movement to aid in body awareness. The limbs to be exercised were always located so as to traverse within a Virtual Interactive Space - VIS (Brooks 1999) – volumetric or linear - with a silent ‘rest’ area adjacent.



**Figure 2:** *Extension of leg through interactive sound space exercise: The solid white oval marks the active sense space. The dotted line indicates the foot motion through the active space. The foot starts at the perimeter of the active space and traverses across which results in a scalar tone feedback of a musical instrument, for example a piano. The participant with eyes closed listens to the tone and controls the phrasing and direction of the scale, ascending or descending. This was also programmed to be a familiar melodic tune.*



**Figure 3:** *Balance exercise: Working with the neglected left side of the patient he faces a large reflector on the wall and closes his eyes as he traverses across the invisible active space towards the author who stands by to assist. The white line marks the body points that active the sounds. This was the best sonic exercise for the male participant as he was incrementally more responsive to visual manipulation as reinforced feedback.*



**Figure 4:** *Cognitive independence exercise: The movement of the hand in the active (white O) space controls the movement and colour of the light (the triangle on the facing wall) and a 'freeze' pedal under the table out of sight of the participant 'freezes' the position. The participant manipulates to a target on the far wall.*

### 11.3 Noteworthy incidences

One patient, 63 years of age male who suffered a haemorrhage in the left side of the brain in 1999 had limited observed auditory response in the sessions (figure 3). He informed us that he was a visual artist who had never had any interest in music, and gave a catalogue of his work to the author as a gift in his second session. One visual piece from the catalogue was replicated by the author on the computer so that the man could move his hands between a red, green, and blue filter opening program sensor array and paint the sequence of images that formed the digital version of his piece of art. A major motivation shift occurred through this for him and it is a good example of how the system has to be capable to immediate change to user preferences.

Other exercises that were notably very successful involved the setting up of a sequence (MIDI) of musical tones that constituted a familiar melody and was playable by event triggering through limb movement. This became a phrasing exercise which enabled control relative to desired goal (see figure 2). Another popular exercise was in using an intelligent light scanner that was interfaced to the sensors so that movement of a limb controlled movement of the light image. In this case, with a task given to move the light to a predetermined target usually high on the far left wall, the participant would move a hand in one sensor space to control the horizontal (X) trajectory; then once satisfied to the strategy, they then had to hold that position and press a 'freeze' pedal which was out of sight under the table. Similarly for the vertical (Y) trajectory a movement, a hold and a 'freeze' pedal press. This was perhaps the greatest success as a cognitive independence exercise which was specifically task oriented with a very physical feedback (see figure 4).

### 11.4 Results

All of those that attended the sessions over the three weeks gave positive response in interviews. They had many ideas following the introduction to the SoundScapes system. Adaptability was a key component so as to be able to fit each individual preferences and limitation. The auditory feedback worked for all but the man who never listened to music mentioned in 11.3 above. All felt that given time they could use the system and thought the home based idea linked by internet a good idea. They also liked the idea of family involvement.

## 12. CONCLUSION

The feasibility study (phase 1) presented in this paper was seen by the Danish government body and CRBI as a successful first phase towards the design and realisation of a product and the development contract did in fact follow as a result of this initial study. The small number of participants (5), all positive in the interviews, however could be pointed to as insignificant in number for a research study and the 'loose' methodology implemented in the sessions was not conclusive to a 'hard science' result. The limited time frame of sessions with such a diverse group was also a restriction. A subsequent publication will detail the research for the full product development at CRBI where a larger user group was tested over a longer time period in phase 2.

**Acknowledgement:** Notably I would like to mention the CRBI ex-Director M. Pinner and physiotherapist G. Thorsen who were the ‘Year of The Brain’ visitors who initiated the start of the collaboration. Coordinator/secretary L. Lambek, external project coordinator P.K. Larsen, and psychologist E.B. Lyon, all who were with the project for the duration at the Centre - thanks. Others have contributed to the research along the way and whilst I am informed by the CRBI that there is no need to credit names the hard work of Physiotherapist J. Sorensen and Psychologist P. Pipenbring in phase 2 must be mentioned, and similarly H. Mølmark & P. Forster in phase 1. All of the ‘students’ involved in the sessions and all of the staff at the Centre for Rehabilitation of Brain Injury for giving such fantastic hospitality during the collaborative years when I was based there. Thanks to the Danish ‘Erhvervsfremmestyrelsen’ and ‘The Egmont Fund,’ Denmark who were involved in funding the project, also to my equipment sponsors ‘Soundbeam’ of Bristol in the UK, IBM for continued support and Martin Lights Denmark for the gratis loan of equipment.

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## APPENDIX 1: PHYSIOTHERAPEUTIC TESTS

Baseline tests: Carried out after the traditional rehabilitation program at the CRBI - *Repeated* before & after test period.

- Grooved Pegboard (Reitan, *et al.*, 1992.)
- Halstead's Finger tapping test (Reitan, *et al.*, 1992.)
- Åstrands Bicycle ergo meter test – measurement of general fitness (Asmussen, *et al.*, 1980.)
- Brief Fatigue Inventory (BFI) (Mendoza, *et al.*, 1999. See also BFI hyperlink.)
- Joint flexibility of involved joints (Pain inventory). Manually measured (angle) by physiotherapist.
- Measure of strength of involved muscle groups (Pain inventory).
- Functional Quality of Movement (FQM) inventory in ADL (Brown *et al.*, in press).
- Berg Balance Scale - dynamic balance (Berg, *et al.*, 1989 a & b; 1992 a & b; 1995).

## APPENDIX 2: PSYCHOLOGICAL TESTS AND INTERVIEWS

- Rotter's Sentence completion test (Rotter *et al.*, 1947; Gerhardt, 1995.)
- Brick Test<sup>iv</sup>
- The Creative Function Test (Carlsson *et al.*, 2000.)
- Tinker Toy Test (Lezak, 1995.)
- Rosenberg Self-esteem Scale, RSES (Rosenberg, 1965; Crandall, 1973; Wylie, 1974.)
- The Tennessee Self-concept Scale, 2<sup>nd</sup> ed. (Fitts *et al.*, 1996.)
- General Well-Being Schedule (Dupuy, 1978, Murrel, 1999.)
- Becks Depression Inventory (Beck, 1961; 1987.)
- Dedicated semi structured interview.
- Focus group interviews including all patients. Led by a psychologist and recorded on video. Experiences, ideas and criticisms are summed up (phase 2 only.)

## APPENDIX 3: USER INTERFACE QUESTIONNAIRE

The Questionnaire was designed with open-end questions especially for use with the Humanics project. It addressed two main areas:

- Prior experience with Computers
- User interface of the system (ease of use, feedback, inspiration)

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<sup>i</sup> One child of 8 years of age recovering from a brain tumour operation also came once and was highly motivated, however sadly due to reaction to chemotherapy he had to stop his visits.

<sup>ii</sup> For further description of the CRBI rehabilitation program and patients see Pinner in Christensen *et al.*, 2000

<sup>iii</sup> Evaluation methods pertaining to video recordings - evaluation by 3rd party physiotherapists (minimum of two) are considered the optimal solution.

<sup>iv</sup> This test is often cited as a general measure of creativity. The person being tested is asked within a certain time limit to name as many different purposes for a brick as possible.

*NB. The use of (the author owned) equipment in the feasibility study is credited in the report to the Danish authorities as having belonged to the phase 2 commercial contractor Personics. This is incorrect. TB*