CAMERA-BASED SOFTWARE IN REHABILITATION/THERAPY INTERVENTION

Brooks, Anthony Lewis

Published in:
Journal of Accessibility and Design for All

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Journal of Accessibility and Design for All
(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

CAMERA-BASED SOFTWARE IN REHABILITATION/THERAPY INTERVENTION

A.L. Brooks
Associate Professor
School of ICT, AD:MT, Medialogy, Aalborg University Denmark

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

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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).

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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. 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

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

interactive audio-visuals performance. A follow-up study concluded that the system tool, VividGroup's Mandala Gesture Extreme (GX), was expensive and requiring an elaborate 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 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

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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.

2.1 Camera-based sensing systems in SoundScapes

Comentario [rv2]: Do not understand this numeration.

Is the level correct?
Should the *2.1* be erasen?

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 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.

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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.

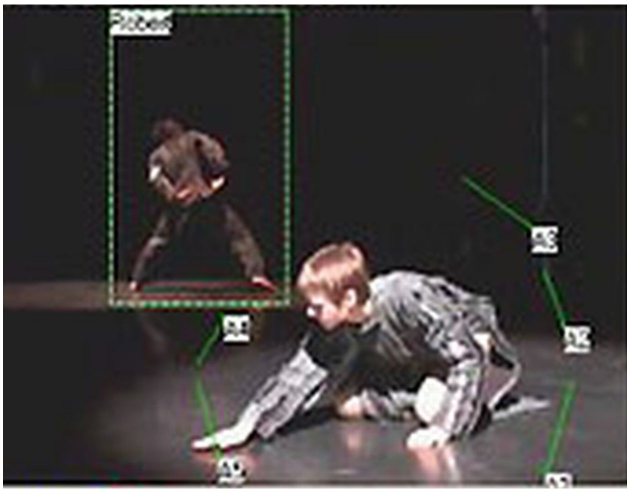
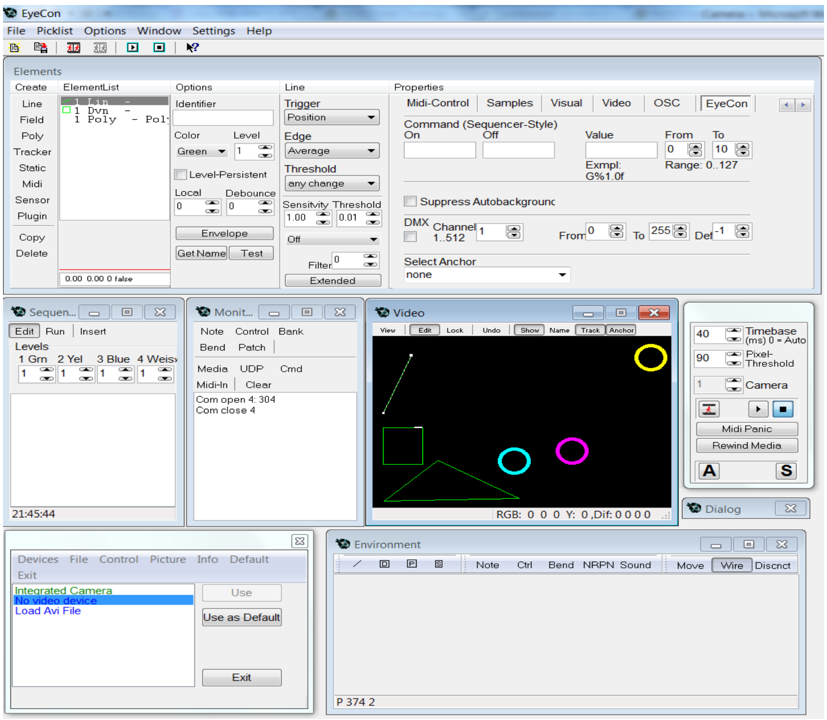


Figure 2. EyeCon interface window in test mode. Source: © EyeCon.



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

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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.

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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©.

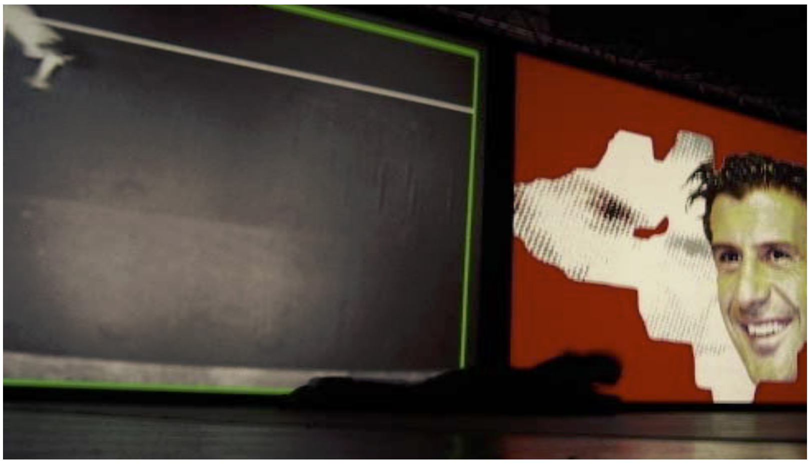


Figure 4. EyeCon (left screen) plus Eyesweb (right screen) software (split camera feed) - Dynamic zones (rectangles) are mapped to music loops and digital painting where the gesture dynamics determine colours and images. SoundScapes©

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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.

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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-

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

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.

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

(CC) JACCES, 2011 – Special issue: 233-246. ISSN: 2013-7087

References

[1] A Camurri, S Hashimoto, M Ricchetti, A Ricci, K Suzuki, R Trocca, and G Volpe (2000), EyesWeb: Toward Gesture and Affect Recognition in Interactive Dance and Music Systems. *Computer Music Journal*, **24**, 1, pp. 57-69.

[2] R Kizony, N Katz, H Weingarden, and P L Weiss (2002), Immersion without encumbrance: adapting a virtual reality system for the rehabilitation of individuals with stroke and spinal cord injury. *Proc. 4th Intl Conf. Disability, Virtual Reality & Assoc. Tech.*, Veszprém, Hungary, pp. 19-26.

[3] E Petersson and A L Brooks (2007), ArtAbilitation®: An Interactive Installation for the Study of Action and Stillness Cycles in Responsive Environments. *Proc. Biennale of Electronic Arts Perth: CADE: Computers in Art and Design Ed. Conf.*, Perth, Australia, pp. 159-170.

[4] P L Weiss, D Rand, N Katz and R Kizony (2004), Video capture virtual reality as a flexible and effective rehabilitation tool. *NeuroEngineering and Rehabilitation* , **1**:12

[5] C Williams, E Petersson, and A L Brooks (2006), Picturing Sound – An overview of its efficacy. *Proc. ArtAbilitation in 6th Intl Conf. Disability, Virtual Reality & Assoc. Tech.*, Esbjerg, Denmark. (n.p.)