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An Internet of Things Resource for Rehabilitation

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Abstract — Evolving from a mature body of research titled SoundScapes, this paper reports on a work-in-progress that is investigating the need that is evident for improved information and recommendation infrastructures to assist in healthcare intervention and communication (including apparatus and method). The need is due to increased ICT use and the potentials for positive treatment outcomes from informed decision-making. A challenge is security of sensitive data, however detailing this is beyond the scope of this paper. In line with this need, an evolving cloud-based collaboration infrastructure resource is reported where global networks of professional subscribers will have increasing access to specific profile data and recommendation strategies. The focus on this phase of the work is to network those using (or considering using) ICT in wellness/QOL, rehabilitation and habilitation. The resource is being built from real-world case studies and is envisioned as a developing “feed-in feed-out” entity where evidence-based findings are submitted and extracted via a secured ‘gateway’ by expert professional practitioners. The resource is considered an ‘Internet of Things’ model to also inform and consult families of people diagnosed with impairments or patients undergoing treatment. Recommended intervention apparatus include bespoke/custom systems as well as commercially available systems. ‘In-action’ and ‘On-action’ models for have emerged from the research. This means that therapists adopting ICT into their work have a wealth of prior studies to guide their choices of hardware, software and intervention method and analysis without having to wade through academic or scientific articles, papers and book chapters. Through dissemination of the concept at this early phase of development in establishing the resource, an open invitation for peers and related interested parties to critique, advise, and otherwise contribute toward optimal development and wide impact is offered.

Keywords—cloud-based collaboration resource; communication; Internet of Things; therapy, rehabilitation, and healthcare

I. INTRODUCTION

This ‘position’ paper introduces a cloud-based convergent infrastructure concept that acts as a resource to bring together disparate and related healthcare professionals and researchers using, or wanting to use, ICT. The goal is to improve communication and knowledge sharing to benefit the local,

national and international healthcare and related fields. It is considered as a disruptive innovation of traditional strategies.

Disruption is acknowledged as a powerful body of theory that describes how people interact and react, how behavior is shaped, how organizational cultures form and influence decisions, and how education can be improved [1, 2, 3, 4]. Innovation is the process of translating an idea or invention into a product or service that creates value or for which customers will pay [5]. Disruptive innovation in context of the authors’ body of work relates to how development of a cloud-based converged infrastructure resource can benefit professionals in the fields of healthcare and rehabilitation.

The concept was conceived under the SoundScapes research resulting from extensive periods of institute-based experimental research since the mid-eighties that included an intense six-year research study across clinics, hospitals and institutes with patients and staff. The first publication was in Japan 1999 [6], and subsequently under a national funded (Danish) healthcare project titled Humanics (1996-2002) – as reported in [7, 8], the original concept was how the Internet can be a communication and reporting network between healthcare professionals and patients who train at home via Virtual Interactive Space (VIS) [6]. The research explored serious games and creative expression (music-making, digital painting and robotics control) – all via unencumbered gesture using bespoke non-worn sensor apparatus. Furthermore, the research includes groundbreaking early work [9], in conceiving and defining non-formal learning and ludic engagement designs stressing a user-centered design approach to learning, cumulated in the development of dynamic pedagogical models [9-21]. These models questioned existing traditional formal pedagogical models that increasingly are reflected upon by contemporary scholars as being redundant as advances in ICT evolve curricula, educational and therapeutically activities and strategies.

In line with related advances and more efficient and speedier network infrastructures the concept has since been refined and extensions planned as a secure accessible data and knowledge repository, virtual consultancy, networking, and training resource to inform and support fields of researchers, practitioners and professionals. It is now envisaged as a

growing and evolving entity where software (e.g. apps, presets, etc.) for in-session intervention and new assessment tools are shared. Cloud-based AI and recommendation engines will support directing global networks of subscribers to relevant information including methods, use-strategies, and products.

Mindful of this vision, this position chapter next introduces the concept of cloud-based infrastructures as disruptive innovation in healthcare and rehabilitation. Cloud-based in context relates to associated means of connectivity, sharing and networking via e.g. virtualization, BYOD (bring your own device), self-forming and mesh networks, and IOT (the Internet of things). Exemplifying the authors' position in the field, the chapter follows with an overview of the mature research and examples of development from the authors' SoundScapes / ArtAbilitation / GameAbilitation and Ludic Engagement Designs for All (LEDA) body of work. This research illustrates of how serious games (structured interactions), computer-generated alternative realities and (playful) play aligned with complementary creative expression designed sessions (abstract or free interactions) can supplement and potentially even supplant traditional methods of intervention in rehabilitation and therapy. Challenges and problems to fully realize potentials of basing aspects of the work 'in the cloud' are discussed. A focus is to optimally engage and immerse the participant (or patient) in the computer-generated environment to maximize the experience toward a state of presence to realize targeted progress and outcomes. A section on these human traits follows later in the paper.

The next section overviews cloud-based computing. This information is generally well known and easily resourced, however, to explain the design of the concept it is considered necessary to include.

II. CLOUD-BASED DISRUPTIVE INNOVATION

The history of cloud computing dates from the 1950s when large mainframe computers were networked with access from various optimized locations. Associated is the authors' tacit knowledge gained from having worked throughout the 1980s on networks of industrial control systems (ICSs) and distributed control system (DCS) in the form of large Honeywell TDC2000 mainframe computers that were accessed 24/7 from a network of remote terminals capable of monitoring and operating a physical environment.

Advantages of adopting cloud-based infrastructures in healthcare and rehabilitation are many. The client site (e.g. hospital, clinic or institute), independent healthcare professional, or even the patient, doesn't have the problem of software integration as any problems, updates, performance and maintenance are addressed by the vendor's expert team who ensure a secure service accessed via HTTP. The costs are predictable (usually a monthly subscription) and costs are distributed. Disadvantages include that whilst the service can be customized for the largest clients, the smaller customers need to accept the service as is. Another potential problem could be that as a critical service is supplied the customer has limited control and needs to rely on the vendor.

Cloud-based computing allows users to benefit from integrated convergence of technologies without the need for

deep knowledge about or expertise with each one of them. The concept in the specific context of this publication aims to unite and link healthcare professionals and related communities around communication (data, information and knowledge) and training (pedagogy, methods, strategies, and apparatus – hard/software) repositories where secure exchanges, sharing and networking is available. Goals include increased efficiency of practice (intervention, evaluations and refinements) and investment (e.g. optimal use of purchased systems) as well as access to latest tools (e.g. digital assessment etc.). Addition benefits are help for the users to enable a focusing on their core business instead of being impeded by IT obstacles.

Mell & Grance [22] defined Cloud Computing via identifying "five essential characteristics", these are:

On-demand self-service. A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

Broad network access. Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

Resource pooling. The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.

Rapid elasticity. Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear unlimited and can be appropriated in any quantity at any time.

Measured service. Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

Virtualizing of IP and Fiber Channel storage networking allows for single console management, pooling and sharing of IT resources. Thus, rather than dedicating a set of resources to a particular computing technology, application or line of business, converged infrastructures, a pool of virtualized server, storage and networking capacity is created that is shared by multiple applications and lines of business - in this context the global healthcare community – including e.g. hospitals, institutes, clinics, General Practitioners (GPs). These end users access the scalable cloud-based applications through a web browser, thin client, or mobile app while the business software and user's data are stored on servers at a remote location i.e. allocated space for a user to deploy and manage software "in the cloud". Thus, a BYOD (bring your own device) becomes feasible. Further Mell & Grance [22] state:

A cloud infrastructure is the collection of hardware and software that enables the five essential characteristics of cloud computing.

The cloud infrastructure can be viewed as containing both a physical layer and an abstraction layer. The physical layer consists of the hardware resources that are necessary to support the cloud services being provided, and typically includes server, storage and network components. The abstraction layer consists of the software deployed across the physical layer, which manifests the essential cloud characteristics. Conceptually the abstraction layer sits above the physical layer.

Service Models:

Software as a Service (SaaS). The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

Platform as a Service (PaaS). The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

Infrastructure as a Service (IaaS). The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

Deployment Models:

Private cloud. The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

Community cloud. The cloud infrastructure is provisioned for exclusive use by a specific community of consumers

from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.

Public cloud. The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.

Hybrid cloud. The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

Deployment models such as the private and community models above relate to the Humanics concept resulting from the authors' SoundScapes research as discussed in the next section. This is where clinics with their teams of experts metaphorically act as the "provider" with patients' linking in as "clients" (but where the Danish welfare state pay for the service).

III. SOUNDSCAPES

SoundScapes is a mature body of research and development that has been well published in that it explores bespoke behavior training interventions via ICT that are specifically tailored for individual participants undergoing rehabilitation to creatively express, play and perform. The ICT strategy integrates various elements from serious games, alternative realities and play. Such integration could one day be cloud-based.

Unlike certain definitions of serious games that disregard entertainment when used in healthcare and rehabilitation [e.g. 23, 24], the concept of SoundScapes holds entertainment of the participant as a key in-session goal. Entertainment experience in this context is designed for and regarded as a catalyst that engages the participant through the fun, enjoyment and pleasure of participating in the activity. The activity is designed as a rehabilitation intervention in line with a healthcare team's goal for the participant's progression where 'actions' are the main unit of analysis. This refers to systems focusing on usefulness, rather than being designed to support ludic values by being ambiguous and open-ended [25]. Thus, systems that promote fun and enjoyment should not be concerned with achieving clear goals, or be overly structured with defined tasks [25, 26].

The SoundScapes hypothesis is that the effect of the intervention is stronger when the participant is not focused on the rehabilitation goal or therapy situation, but rather to have fun in the moment. Cook [27] emphasizes that *ludicity* (having fun) is far more than simply playing a game. It relates to the engagement of the body and mind, where a ludic activity is something that can create a good feeling for a person. In terms of Petersson [9], and Petersson Brooks [11], this constitutes a

crucial foundation for learning. However, this is problematic and an ongoing challenge to achieve through for example personnel or situation influences. In line with this was how SoundScapes targeted online intervention with interactive gesture controlled games, digital painting, and music making when researching with acquired brain injured patients in the Humanics project (1996-2002) – see [7, 8]. A concept behind the authors' design being that the *tele-abilitation* aspect would place the patient in a home-family situation where the playing or creative expression would optimize distancing from the therapy situation. However, from that distance, game interactions and results could be conveyed as shared data to a clinic for analysis for the assigned healthcare professionals (physical and occupational therapists, psychologists, neuropsychologists and speech therapists) to give feedback without the necessity of travelling and expense. Parallel to the Humanics study was a European FET (Future Emerging Technology) project that also resulted from the authors' earlier research where additionally non-humanoid robotic devices were controlled by gesture (via both worn or non-worn sensors) as a healthcare intervention to supplement traditional methods - see [28, 29]. In the authors' SoundScapes research interactive computer-based gesture-controlled serious games have been explored since 1998. Prior to that interactive music making and sound manipulation was primarily used. Serious Games is briefly introduced next.

IV. SERIOUS GAMES

The term *serious games* is used in reference to any kind of online game for learning where the games are designed with the intention of improving some specific aspect of learning that is relevant, instantly useful, and fun [30]. However, the players come to serious games with expectations of learning. It is such expectation of outcome that is considered non-optimal in SoundScapes as it has been evident that participants push their physical limitations when they are motivated through engagement to achieve the state of flow [31], present and immersed in the activity, rather than thinking of the consequences. In other words when an activity necessitates a physical input to trigger and manipulate multimedia the physical actions give proprioceptive feedback to the participant and that is where a focus begins in an interaction. The goal is to transfer the participant's attention away from the primary and to the multimedia (i.e. secondary) feedback so it is that stimuli that drive subsequent (inter)actions. This causal activity results in the human afferent efferent neural feedback loop closure.

Derryberry [30] argues that serious games “offer a powerful, effective approach to learning and skills development”. Furthering her position, she states, “What sets serious games apart from the rest is the focus on specific and intentional learning outcomes to achieve serious, measurable, sustained changes in performance and behavior. Learning design represents a new, complex area of design for the game world. Learning designers have unique opportunities to make a significant contribution to game design teams by organizing game play to focus on changing, in a predefined way, the beliefs, skills, and/or behaviors of those who play the game, while preserving the entertainment aspects of the game experience.” (p. 4)

Salen and Zimmerman [32] argue a game that is well-designed yields meaningful play defining it as “what occurs when the relationships between actions and outcomes in a game are both discernable (*sic*) and integrated into the larger context of the game.” In context to SoundScapes and the use of games in rehabilitation and healthcare, a refinement of meaningful play is posited as *what occurs when the relationships between actions and outcomes in a game are both discernable and integrated into the larger context of the situation*. This is where ‘situation’ includes the targeted progression according to the participant's profile where actions and outcomes are key units of analysis in SoundScapes of both the digital media and human performance. Thus, by elaborating beyond ‘the larger context of the game’ to ‘the larger context of the situation’ It is acknowledged, “there is widespread consensus that games motivate players to spend time on task mastering the skills a game imparts” [33]. However, this author argues that when a game is conceived for use in healthcare, the gameplay skills in the computer generated alternative reality need to be designed balanced and aligned to the skill involved in interaction in order to increment a patient's progress target of physical improvement. In other words a focus must be on physical input or functional improvement that is mapped accordingly to stimulate repeated training to achieve in gameplay. Advances in affordable game input devices and accessible mapping software to digital content increase potentials of what is possible through using serious games in this context. Petersson Brooks and Borum [15] emphasize that this is not enough and that there is an urgent need for a user-centered design approach to learning and therapy. In line with Murray [34], the author emphasizes a particular focus on the combination of procedural and human-directed affordances. When these two affordances fit together well, they create the satisfying experience of agency. Such a human-centered design approach builds on a pragmatist notion of action as developed by Dewey [35]. This offers an understanding of gameplay as an emergent, situated and reciprocal process comprising (inter)action as well as an interplay between the subject(s) and the environment (cf. [9]). Therefore, Murray's suggested focus is based on Petersson [9], Petersson Brooks [11] and Petersson Brooks and Borum [15], extended to include the digital space as well as the physical place, which also can be considered as spaces for design with an active involvement of users. In this way, people engaged in rehabilitation (and learning) are designers planning for something to take place.

V. ALTERNATIVE REALITY

Computer-generated Alternative Reality (e.g. of a game or creating art virtual interactive space) can be designed according to the personal profile of the participant and the goals of the sessions. The goal is to engage the participant in activities that comprise the alternative reality. Such engagement relates to immersion, presence and flow, human traits that relate to play and useful in treatment in healthcare and rehabilitation. The next section analogizes such traits from a games perspective.

A. Analogizing from a Games Perspective

In a 2012 National Science Foundation (NSF) publication titled Interactive Media, Attention, and Well-Being¹, the executive summary states: -

Behavioral training interventions have received much interest as potentially efficient and cost-effective ways to maintain brain fitness or enhance skilled performance with impact ranging from health and fitness to education and job training. In particular, neuroscience research has documented the importance of explicitly training (i) attentional control, in order to enhance perceptual and cognitive fitness as well as (ii) kindness and compassion, to produce changes in adaptive emotional regulation and well-being. At the same time, video game play has become pervasive throughout all layers of current society, thus providing a potentially unique vehicle to deliver such controlled training at home in a highly engaging and cost-efficient manner. Yet, several gaps remain in terms of realizing the true potential of the medium for positive impact, as developing engaging and effective research-based games anchored in neuroscientific principles that can have scalable, sustainable publishing models presents several new interdisciplinary challenges.

A panel of international experts associated to the National Science Foundation (NSF) then identified in the same document (ibid) five main areas of focus toward improving the scientific validation of games designed to boost well being or attention:

*(i) **Better understanding of core game mechanics driving impact outcomes.** Clearly not all games are created equal when it comes to fostering brain plasticity – some game mechanics appear more efficient than others, calling for a concerted effort in characterizing those game dynamics that are most potent in inducing brain plasticity and learning.*

*(ii) **Incorporating inter-individual differences in game design.** Recognizing that there are as many ways to play a game as there are players and experience levels, the need to acknowledge and exploit inter-individual variability was highlighted, calling for the design of individualized game experiences taking into account not only game play, but also physiological and brain markers in real time.*

*(iii) **Greater focus on social and emotional skills.** The fact that emotion and social conduct may be considered skills rather than traits, and thus like all skills can exhibit sizeable plasticity, calls for more games designed to impact affective states.*

*(iv) **Clearer validation methodologies and benchmarks.** Not a week goes by without some new claim about a new piece of software curing ADD/ADHD, or a new mini-game that slows cognitive aging. Yet, few of these statements withstand scrutiny. A hot debate about best methodological and reporting practices is thus underway in the field. In addition, objective demonstration of efficacy calls for larger multi-site studies, and possibly an*

infrastructure allowing independent evaluation of game/intervention efficacy.

*(v) **Developing sustainable, scalable publishing models.** Translating in-lab research documenting a beneficial effect of video games on attention or well being into a commercially viable product that can reach many people and truly produce social change is a tall order. Lessons could be learned from the pharmaceutical industry, but alternate paths may be worth considering for behavioral interventions, such as through video games.*



Figure 1/1. Dolphin game with therapist



Figure 1/2 Dolphin game alone



Figure 1/3 Hand zone dynamic

¹ http://www.bcs.rochester.edu/games4good/GameWellBeingAttention_NSFReport.pdf



Figure 1/4. Hand dynamic

Concluding the executive summary (ibid) the report states the need for “New approaches to the design, assessment, publishing and on-going optimization of video games for enhancing well-being and attention ...” where users and researchers can access and control the mechanics identified to foster brain plasticity to “thus adapt the games to their needs not only for play, but also for research.” An example of such tailoring of bespoke games is shown in figure 1 from the Humanics study as the CRBI (Centre for Rehabilitation of Brain Injury) an acknowledged leading center for acquired brain injury treatment in Denmark, which is located adjacent to Copenhagen University. With Multiplayer online games already networking global players the serious games and interactive content should be easily transferred to the cloud.

The images in figure 1 from top to bottom illustrate how in a treatment program for acquired brain injured patients early intervention was designed so that the session facilitator (in this case a physiotherapist) was active as a sparring partner to make the patient feel at ease and to direct and assess the participation, motivation and engagement. The increased social interaction was found to be positive and aided the patient’s understanding of the task. The game was an animation of a dolphin (wireframe to prevent jitter) made in ‘Macromedia Flash’ (now ‘Adobe Flash’). Two non-invasive sensors were used, one to empower horizontal arm/hand gesture to control the dolphin’s horizontal travel (left-right), and the second to empower vertical gesture to control the dolphin’s vertical travel (up-down). The goal was to eat the smaller fish in the surrounding sea by swimming over them and evading a jellyfish, which ended the game if contacted. The first sessions involved the facilitator controlling one sensor and the patient the other sensor with his Hemiparesis arm (top picture). When assessed competent, the patient operated both sensors alone (second picture). Following the solo fish game, exercises for dynamics of motion of Hemiparesis side are used (third picture). This is where an animated ball held by an animated hand/arm is released providing the Hemiparesis motion dynamic is above a selected threshold through the sensing space. Another game used was eye-hand responses to friction changes on an animated glass resting on an animated tray. Such games are adaptive and tailored to an individual’s profile.

Outcomes from SoundScapes, whilst positive, suggest that video games have a restrictive tree-based structure constraining

suitability optimal for only certain scenarios and conditions. Abstract digital creativity via unrestricted gesture-control, in the form of music-making, painting, and robotic lighting has a differing structure and is suitable for certain scenarios and conditions. The argument is hereby made that these structures are complementary, exhibiting common and differing aspects where play and social/machine interactions are central.

The NSF report suggests how expert brain scientist evaluations would identify control points of successful games so that rigorous experimental systematic research would highlight impact on brain plasticity, learning and modification of cognitive processes. In order to achieve advancements in this necessitates acknowledgement of the involved disciplinary differences would be in order where the scientists establish key parameters and dimensions hypothesized to affect and nurture plasticity in terms comprehensible for the video game industry experts. In line with this, the argument made herein, supported by this authors’ prior publications (and others), highlight how afferent efferent neural feedback closure in the way described affects and nurtures brain plasticity through advanced understandings of media plasticity manipulation [19]. The further argument of the common structures between using ‘art’ and games in this context widens the hypothesis so that fertile research is conducted having common societal goals.

However, many contemporary formal treatment programs e.g. using games in rehabilitation intervention do not balance the structured (formal) with the abstract (non-/informal). This strategy in SoundScapes is addressed via the concepts of GameAbilitation (tree-based structure) and ArtAbilitation (non-figurative), which balance as selectable content under the LEDA (Ludic Engagement Designs for All) concept where fun is the targeted end-user experience – in line with Cook [27]. However, underpinning each form under the SoundScapes umbrella is a specific strategy for improved human performance, as well as increased quality of life and wellbeing. N.B. As an ongoing work-in-progress SoundScapes has been published elsewhere to elaborate the various aspects to give the reader a holistic perspective on the work. The work started around the mid-eighties.

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