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Brooks, Anthony Lewis

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Human Computer Confluence in Rehabilitation: Digital Media Plasticity and Human Performance Plasticity

Anthony Lewis Brooks

Aalborg University Esbjerg, Niels Bohrs vej 8, Esbjerg, Denmark
tb@create.aau.dk

Abstract. Digital media plasticity evocative to embodied interaction is presented as a utilitarian tool when mixed and matched to target human performance potentials specific to nuance of development for those with impairment. A distinct intervention strategy trains via alternative channeling of external stimuli that bypasses desensitized/dysfunctional sensory pathways to close the afferent/efferent loop. Designing method and apparatus to optimize participant motivation is core of the emergent model. Accessible play, fun, and creativity are central as user experiences, rather than traditional therapeutic approaches promoting mindsets and activities commonly considered enduring, mundane and boring. The concept focuses on sensor-based interfaces mapped to control tailored-content that acts as direct and immediate feedbacks mirroring input. These flexible, adaptive, and 'plastic' options offer facilitators new tool-kits for individualized interventions to supplement traditional approaches and strategies. Conclusions point to how required informal/non-formal training of such plastic approaches requires formal accreditation to realize potentials and adoptions.

Keywords: Digital Media & Human Performance Plasticity; Alternative channeling; HCI; Games; Creativity; Brain Plasticity; Afferent-efferent Neural Loop Closure.

1 Introduction

This paper presents a mature body of research exploring *digital media plasticity* mixed and matched to a participant's needs to question alternative channeling of stimuli to affect plasticity of the brain and consequentially plasticity of human performance. This is via achieving closure of the human afferent-efferent neural loop [1, 2, 3]. A supplement to traditional therapeutic/rehabilitation intervention has emerged. Following the introduction of the concept, method and apparatus, a discussion presents the argument of plasticity potentials and how ICT applied within intervention using games and creativity requires advanced training, learning and hands-on experiences. A critical reflection closes the paper stating the challenges of the informal/non-formal approach suggesting possible derailment through lack of authorized formal accreditation being in place to offer would be life-long learners new opportunities.

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2 SoundScapes Concept

Following prototype creation and many years of solo (author) fieldwork, a family of patents resulted on method and apparatus (5/5/2000: US 09/565,924[1]) – see [4]. The research was responsible for national (Denmark) and international projects that subsequently realized a product, commercial company, and dedicated research facility.

2.1 Background

The concept (now a registered company in Denmark) evolved from the author's artist/musician profile having an engineering education and a domestic history, and thus, intimate experiences of family members with profound impairment. The insights to individual traits, needs, desires and preferences led to exploration of digital media's plasticity enquiring adaptability, interconnect-ability, and tailor-ability applied across performance art (stage and installation) and rehabilitation (PMLD). Preliminary research on technological solutions for biofeedback (with a focus on direct cause and effect) led to various prototypes being created and tested in exploratory fieldwork. The devices were basic apparatus that used the MIDI (Musical Instrument Digital Interface) communication protocol that had recently been standardized (1983). Various test instruments were made – predominant was a touch-sensitive MIDI-Bass that could give digital and analogue mixed stimuli feedback (low-frequency audio, image etc.)

Research included inspirational tours, residencies and guest visits at Stanford University Music department; the Mechanical Engineering Department Design Group; the Palo Alto VA Health Care System, Rehabilitation Research and Development Center, California, USA; IRCAM, Paris, France; DIEM, Aarhus, Denmark; Steim, Amsterdam … as well as a number of commercial companies including Biomuse (Biocontrol Systems, Neuro Interactive Technology) [5], and Waverider[2] (MindPeak). These early biocontrol systems were based on electronic signals measured from electrodes precisely positioned on the surface of the skin then mapped to control a computer. Instrumentation amplifier circuits (IA) are used to measure the bioelectric signals from the electrodes that are then sent to a programmable gain amplifier (PGA). The signal is then sampled and processed by a specialized digital signal processing microprocessor in order to filter the signals and then perform specific pattern recognition operations. This processed signal is then sent to the computer using an optically isolated serial channel, which importantly protects the user from voltage spikes coming from the computer. Electronic information was thus sourced from the heart (ECG), brain activity (EEG), sweat (Electrodermal/GSR). More direct and immediately controllable signals, i.e. eye blinks/motion (EOG), muscle tensioning (EMG), were also sourced, reducing lag, optimising desired direct and immediate causality. An issue was that worn 'wet' on-body biocontrol sensors (at that time) required conducting gel

[1] United States Department of Commerce: United States Patent & Trademark Office document.

[2] `http://www.mindpeak.com/WaveRider-Pro.aspx` as performed by author at The EuropeanNetwork for Intelligent Information Interfaces, i3 gala dinner, Basel, 2001.

preparation of the participant that was enduring, uncomfortable, and requiring post-session cleaning. Alongside this was the problematic preciseness of positioning of the sensors for optimal Signal-to-Noise ratio (often abbreviated SNR or S/N), which equates to signal strength. These systems were evaluated as imposing a mindset of 'wired for therapy' and problematic due to need for specific training of possibly technophobic staff where specific knowledge of MIDI (or other) protocol was needed. Thus, a more user-friendly solution was sought.

It was found that if residual movement exists then an increased opportunity is offered to *directly and immediately control* data dynamically via non-worn sensors. A reduced lag factor was evident using off-body infrared sensors compared to worn sensors that source data from inner body signals (e.g. brain, heart, GSR) where 'control' is questionable. Thus, motion of an impaired individual has been the focus of data acquisition in this work to optimize the experience of control for the end-user.

Movement as unencumbered biocontrol. Awareness of one's body differs according to each person, and especially in the case of impairment, condition and situation. In line with this, research presented how the US Federal government acknowledged how pleasure derived from movement, alongside the empirically supported premise that the body, mind and spirit are interconnected has resulted in associations for dance and movement therapy where psychotherapeutic use of movement benefits the emotional, cognitive, physical and social integration of individuals[3]. The link between motion-pleasure to human performance was furthered via a U.S. National Science Foundation report from 2002, titled *Converging Technologies for Improving Human Performance* [6] where disability and healthcare issues are in focus. The plasticity of digital media is suggested in this report. It is this form of 'convergence of technologies' thinking, wherein innate flexible potentials to mix'n'match in order to address individual needs of impairment, that are in focus herein and in the author's earlier publications [e.g. 1, 2, 3, 4, 7, 8, 9, 15]. The SoundScapes research (including *ArtAbilitation, GameAbilitation, Ludic Engagement Designs for All [LEDA]*) therefore evolved to create devices and systems for investigation of non-worn sensors, in other words where unencumbered free gesture (nothing held, or attached) in an invisible sensing space - referred to as "Virtual Interactive Space" (VIS) [1] – generated control data. The focus on systems that required no participant preparation, discomfort, or post-session cleaning meant that participants could enter the session room and immediately begin before getting tired or distracted. The developed prototypes also required no strength or dexterity to operate as mapping software enabled scaling and other decisions related to multimedia content so that tailored solutions were apparent. A situation thus evolved where it was no longer questioned *what one could do with these systems* but rather design decisions had to be made as to *what not to do*. The decisions were determined on the participant/patient profile, therapist/doctor goal from sessions, and the available system components available e.g. interfaces, mapping software, multimedia content, and presentation equipment. The early interface sensors and system developments are outlined in the next section.

[3] `http://www.adta.org/About_DMT`

2.2 SoundScapes - Non-worn Biocontrol Sensor Systems

The development of the SoundScapes non-worn sensor-based interfaces focused on infrared technology with multiple sensor arrays (figure 1). Ultrasound, camera (figure 2), and later, laser technologies were integrated so that increased mixing and matching options were available to session designers and intervention facilitators.

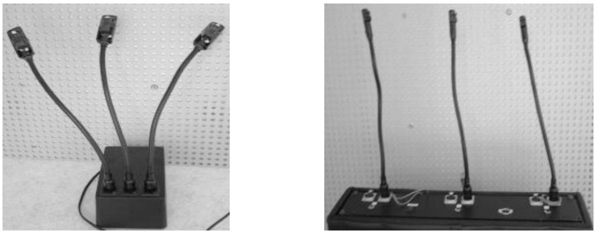

Fig. 1. Infrared prototypes with 3 heads for RGB filter control of image; manipulation of three MIDI instruments; or three properties of robotic device or game control via gesture alone

Development was aligned with multimedia growth and advancements in sensor technologies, computer hardware and software. Alongside was increased ICT pervasiveness in society. The use of multiple interface technologies having differing sensing profiles (where the invisible space can be volumetric/3D, linear, or planar according to technology used - figure 2) preceded contemporary mixed-sensing inventions such as the Nintendo Wii and Microsoft Kinect (see later references in following sections).

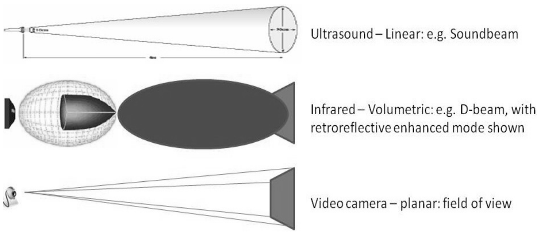

Fig. 2. Non-invasive sensing profiles

2.3 Acceptance by Institutes

Following preliminary research that resulted in prototype creation, the early proof-of-concept was an enduring challenge to gain acceptance of the SoundScapes' sensor-based interfaces and gesture-control of games and art/creative play within rehabilitation and healthcare. However, demonstrations and subsequent residencies illustrated to healthcare professionals and families the end-user positive responses to the untraditional intervention with fun and creative activities. Following rigorous testing, assessments, and evaluations by various experts, SoundScapes was adopted into a select number of institutes in Denmark in the mid nineteen nineties. A product prototype was realized as a multi-institute commission in 1998/9 whereby intervention training and evaluation supported the author's apparatus and method concept. Adoption followed leading to product and company creation. The addressing of future society demographics through ICT was especially in focus, especially the predicted increased aged and impaired communities alongside associated service care industries. Unemployment is a related issue, which is detailed elsewhere in the author's publications. Models have thus emerged from SoundScapes that are offered for peer augmentation to improve on the method, apparatus and testing [7].

2.4 Moving beyond Own-created Apparatus

Following the early years of developing devices, it became clear that commercial equipment offered more affordable solutions providing that the mapping software could be programmed to control selectable open content to be adapted to an individual. Explorations of game peripherals included the Sony EyeToy [8] and Nintendo Wii [9]. However, both companies responded negatively to approaches to open the game content. More recently, 3rd party software[4] enables open environments for content creation and sensor data mapping. Even basic microprocessors (e.g. MakeyMakey/Arduino) can be mapped to easily constructed video games. The potentials of open-source peripherals has been made apparent by the Microsoft Kinect (and other available time-of-flight cameras and related devices), as evidenced by the huge community of developers creating an array of potential tools available for use in this field considering different needs of 'players'.

2.5 Facilitator Competences and Need for Specific Training Programs

With such progress and activity in digital media plasticity and its potentials in human performance plasticity, the question must be asked of the competences of those facilitating the training sessions. Their understanding of such systems and the required change to intervention strategies that are required to optimize use to maximize patient/participant benefit and progress of development clearly need to be in line with the goals of the therapist or healthcare team. This alignment may be a problem.

From experiences to date, it is posited that this question is not being asked enough as facilitators are utilizing such tools without specific schooling, extra curricula training or even thought (a tendency is to just include a game as an add-on). SoundScapes has thus invested in developing an accessible training/spa/learning-lab complex with accommodation in Denmark in line with life-long learning, games4health, and welfare society (which Denmark is renown for). This is set up as a travel-for-health retreat to train trainers (national/international) via programs on how ICT can be used in healthcare, intervention and learning. The next section overviews aspects of plasticity relating to the SoundScapes' philosophy on facilitator training needs.

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[4] e.g. Osculator `http://www.osculator.net` -- Max/MSP/Jitter `http://cycling74.com` -- Eyesweb `http://www.infomus.org/eyesweb_ita.php` -- Isadora `http://troikatronix.com`, and others…

3 Plasticity

3.1 Digital Media Plasticity

The malleable aspect of digital media, in this work, is tied closely to variance in brain plasticity and of effect on human performance (next section). This research, through a history exploring the plasticity of digital media, creates adaptive situated experiences to stimulate meaningful causal interactions to supplement traditional intervention. It is posited from this research that the brain can be affected by designing specific interactions with stimuli to promote a nuance of participant microdevelopment [10]. An example of this is a case study questioning how the balance sense attribute of a patient with acquired brain injury was lost and then trained via sound that gave feedback according to the body position in space – thus training proprioception/balance [11]. Thus, the activity – be it gaming, creating (art-based), or other control - is optimal if it allows access to parameters for on-the-fly changes according to a participant needs profile, preferences, and progress. In this way it is imperative that a facilitator understands the system to match to the individual and to tailor/fine-tune to the session goal.

3.2 Brain- and Human Performance Plasticity

When one refers to brain plasticity (also commonly called neuroplasticity) it is the neuronal circuits, synapse activities, and malleable qualities of change and subsequent affect on the body's nervous system that are being discussed. These elements change throughout life [12]. When a person is subject to physical injury or impairment these elements and the sensitizing associated to the brain can become damaged [13] leading to disability and need for rehabilitation and therapeutic intervention that involves training and (re)learning. The involved cortical remapping is available into adulthood [14], which presents opportunities for promoting change via alternative channeling of stimuli. It is this alternative non-formal approach that is the core in SoundScapes. Whist fun and enjoyment are seen as the designed-for experience, behind is a profile-dependent purpose targeting nuance of development progress through focused intervention by SoundScapes' trained facilitators. Thus, SoundScapes has evolved from an original invent with a goal of adaptive apparatus and method (as per the published patent) to help as an assistive technology and technique to redirect foci to investigate relations between people and systems wherefrom models emerged both for specific intervention and holistic evaluations: People = Patients/Participants + Facilitators.

4 Discussions

Over the lifetime of this research, the increased plasticity of digital media - i.e. the abundance of opportunities for creation and application - has evolved to effect this work such that it became clear that one no longer questioned what one could do with these systems but rather design decisions had to be made as to what not to do. The redundancy decisions are determined on the participant/patient profile, therapist/doctor goal from sessions, and the available system components available e.g. interfaces, mapping software, multimedia content, and presentation equipment. An even greater factor is suggested as being who the facilitator is and their competence in applying ICT in this form within this context.

Analogizing - A musician has to pick from the available multitude of notes on his/her instrument and then perform with selected available nuances according to interpretation. A painter has to choose colors- raw, mixed and blended- from his/her palette and then apply to a canvas according to an envisioned result. Both are aware of how silence, space, and no color are crucial. These analogies relate to how the SoundScapes designer researches, consults, then selects, mixes, blends, matches and presents the tailored palette of components as an instrument or toolkit for the facilitator to use and improvise intervention in sessions. The delimited choices are created as presets to enable swift parameter change (sensitizing of feed-forward input, mapping, and content) to maintain maximum contact between the facilitator and the patient/participant. Improvised facilitator intervention is based upon the ZOOM (Zone of Optimized Motivation) model of in-action assessment of capacity and increment of challenge [7]. The system designer thus passes over what has been created by him/her for the facilitator to evoke an aesthetic response by mediating the patient/participant's ludic and creative engagement with the system, thus to achieve a representation of the targeted neuroaesthetic resonance [15].

Linking external aesthetic stimuli to affect on the brain and the inner resonance of the patient/participant and subsequent actions [7], a clear causal afferent-efferent neural loop closure is available for closure via the intervention. In line with this is how discussions with neurologists have influenced the author's understanding and direction in creating and evolving SoundScapes. Influence from this work is evident in projects involving neurologists, neuropsychologists, psychologists, physio/occupation therapists, etc. [7, 11] Similarly; other luminaries state the link between the neural and the artist wherefrom an improved understanding of the nature of man is posited, e.g.

> *… neuroscientists would do well to exploit what artists, who have explored the potentials and capacities of the visual brain with their own methods, have to tell us in their works. Because all art obeys the laws of the visual brain, it is not uncommon for art to reveal these laws to us, often surprising us with the visually unexpected. Paul Klee was right when he said, "Art does not represent the visual world, it makes things visible." // It is only by understanding the neural laws that dictate human activity in all spheres - in law, morality, religion and even economics and politics, no less than in art - that we can ever hope to achieve a more proper understanding of the nature of man* [5]

Relating the presented issues of plasticity and how technology offers opportunities to support and complement traditional strategies links directly to designing for specific interactions by people with different needs. Such embodied design of interaction is in line with Dourish [16] who states how "Embodied interaction is not a technology or a

[5] www.neuroesthetics.org/statement-on-neuroesthetics.php

set of rules it is a perspective on the relationship between people and systems. The question of how it should be developed, explored, and instantiated remain open research questions." (p. 192). Accordingly, and as stated earlier, the creation and evolution of the SoundScapes system apparatus and method [4] has at the core held focus on the relationship between people and systems; with the human at the center.

5 Conclusions

This contribution presents a mature body of research exploring digital media plasticity mixed and matched to the needs of a participant. The concept behind questioning and realizing alternative channeling of stimuli to affect the plasticity of the brain and simultaneously the plasticity of human performance is discussed.

Related outcomes involving closure of the human afferent-efferent neural loop is argued in line with the applied use of creativity, play and learning via video games and art as content/experience. Models are introduced, linked and proposed for peer elaboration and improvements. The impact in the field, including product, researches, company spinout, patent, and research laboratory achievements are shared. An ICT supplement to traditional therapeutic/rehabilitation intervention has resulted.

Digital media is discreet in form yet analogous to human use. The improvisation required by the facilitator with the given ICT tools involves a need for training where intimate acquaintance is involved. Innate to this claim are contemporary strategies involving role-play where the facilitator becomes the participant. A facilitator understanding of how inter-subjectivity works and the system linkage is not enough: A requirement for success is where intra-subjective affects are achieved from the inter-subjective – thus, establishing embodied interactions via alternative channeling of stimuli to promote stimulation of brain plasticity and neural re-mappings toward improvements and nuance of development.

The attitude is that the system designer should be creating a piece of art each time s(he) hands over the apparatus to the facilitator. The facilitator implements the apparatus under a method open for creativity and expression where a shared experience with the participant evolves. The participant's experience of ludic creativity and self-expression develops from embodied interactions with the apparatus. Thus, the method as detailed in the patent [4] has evolved to not solely rely on interface apparatus but to be able to adapt and mix'n'match such a design 'toolkit' via mapping software and creative vision of end result potentials. In this way the method, stated in the patent, has evolved to supersede the apparatus as prime invent for this unique communication form to assist in rehabilitation, therapy, and even life quality aspects of society.

To close a reflection is made on how this work has evolved from preliminary research on biofeedback involving the positioning of sensors on the body and head to generate data mapped to manipulate audiovisual representations. The research then created and investigated primarily with non-worn sensor systems to stimulate human affect and this is in line with how luminaries in human research report how media affects the brain [e.g. 17, 18, 19, 20]. Others inform of how perception and cognition are inherently predictive, functioning to allow anticipate consequences of current and/or potential actions [21]. Links to sensation and perception are clear [22], as are the connections between gesture-based communication and human-computer interactions [23]. Mirroring, as afforded by plastic digital media, offers customized means to perceive the self, which can lead to learning awareness, and subsequent training of e.g. psychological phenomena such as proprioception and kinesthesis to assist maintaining balance, coordinate actions, and basic perceptual and memory processes involved in navigation. Such digital mirroring is core to SoundScapes, and in line with [24, 25].

From the applied research to date it is evident that the alternative channeling approach of adapting media plasticity to human plasticity offers opportunities for training that engages participants at a different level than traditional methods. It is therefore concluded that a concentrated effort is needed in research to fully understand potentials. Alongside this is the author's committed investment to contribute by establishing a training facility for professionals and families to school their utilizing of ICT in healthcare, rehabilitation and therapy. A challenge in this is that such informal/non-formal schooling is not accredited so that funding maybe restricted to further or fully realize the potentials such an initiative would offer.

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