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In This Issue

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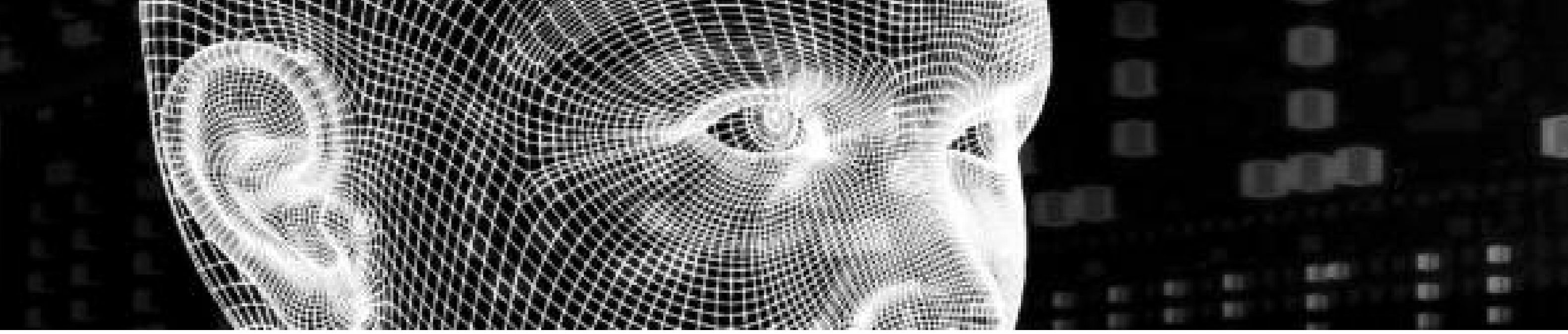

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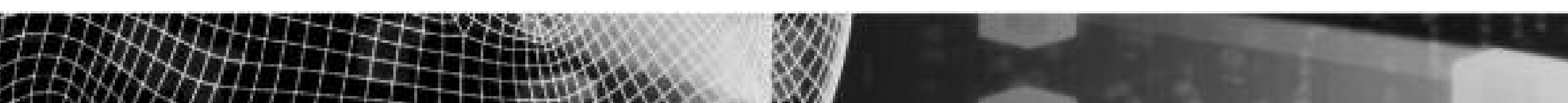

EDITORIAL

Welcome to the Winter 2009 issue of the Journal of CyberTherapy & Rehabilitation (JCR). We are pleased to bring this special issue of our publication to readers, critics and researchers around the world. Our peer-reviewed academic journal explores the uses of advanced technologies for therapy, training, education, prevention and rehabilitation. JCR is a quarterly published academic journal, unique in the fact that it focuses on the rapidly expanding worldwide trend of applying groundbreaking technology towards the field of healthcare. Psychiatry, psychology, physical medicine and rehabilitation, neurorehabilitation, oncology, obesity, eating disorders and autism continue to be main areas of interest studied by JCR.

Since our inaugural issue, JCR has received international attention from peers, international institutions and international conferences. A common thirst for new knowledge and application of cutting-edge technologies to better the lives of others brings this diverse group of people towards a similar goal. Advanced technologies, such as robotics, adaptive displays, E-health, virtual reality (VR) and non-invasive physiological monitoring are now applied to many diverse fields of healthcare. As this body of research is added to, patients, doctors and therapists can look towards a hopeful future and new ways to treat mental and physical disorders. Within this issue of JCR, we present comprehensive review articles submitted by preeminent scholars in the field. The content is diverse, featuring such topics as VR immersions, the effects of video game playing and even online forums to treat sufferers of disease.

This special issue of JCR includes three full papers, as well as all presented abstracts, written by presenters from the "Beyond Brain Machine Interface: Motor, Cognitive and Virtual" pre-conference workshop, held September 2, 2009 in Minneapolis, Minnesota. The conference, co-organized by the Army Research Office, IEEE EMBS and the Interactive Media Institute, educated attendees on more efficient and intuitive ways of achieving system control than manual manipulation and allowed for discourse among academics, members of the scientific community, biomedical device engineers and the clinician user community. Scientists from five different countries and ten diverse institutions gathered to discuss these technologies and developments in their fields of research, and gave formal presentations on their papers.

In this issue's first article Cai, Milcent and Franco explore the human-machine visual digest system by focusing on the relationship between gaze and object. They describe ways to better utilize network bandwidth and in turn, minimize the resulting media footprint by combining human vision and machine vision.

Next, Scherer et al. discuss brain-computer interface research using EEG and ECoG-based paradigms that are presented to the reader, along with ways to improve information transfer rates. Different BCI projects are discussed, such as an anatomically correct testbed for a human hand model.

In the following article, Raspelli et al. conduct further research on the Multiple Errands Test, applying virtual reality to assess executive functions in patients suffering from Parkinson's disease and stroke.

In the fourth manuscript, Pallavicini et al. report findings on a study to treat sufferers of Generalized Anxiety Disorder using biofeedback, virtual reality and mobile phones. The use of mobile phones allowed patients to continue treatment in an outpatient setting and addresses the classic problem associated with VR therapy–the lack of mobility for the treatment system.

Gras, Hummer and Hine, in the fifth manuscript, compare the reliability and validity of the Nintendo Wii Fit to the widely used NeuroCom EquiTest, to measure balance and help rehabilitate patients.

Lastly, Cantelmi and Talli explain the psychological and psychopathological risks associated with overuse of the Internet, including the problems associated with defining a relevant syndrome, possible diagnostic criteria and possible therapies for treatment.

This issue of JCR will continue to explore the ways in which healthcare, in Europe and worldwide, can benefit from the applications of technology. I would like to sincerely thank the contributing authors for their inspiring work and dedication to this field of research. I also want to thank JCR's Associate Editors – Professor Botella, Professor Bouchard, Professor Gamberini and Professor Riva for their leadership and hard work, as well as our internationally renowned Editorial Board for their contributions. We encourage readers and subscribers to contact us with ideas and manuscripts. Your input continues to enrich our publication. Looking to 2010, we are optimistic as this diverse field continues to grow and attract those wishing to learn more and those already supporting and implementing new technologies. With only more room to grow, we will continue to bring you news of further developments in the upcoming year.

Brenda K. Wiederhold, Ph.D., MBA, BCIA
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Journal of CyberTherapy & Rehabilitation
Virtual Reality Medical Institute

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Abstracts from "Beyond Brain Machine Interface: Motor, Cognitive, and Virtual"

September 2, 2009
Minneapolis, Minnesota, U.S.A.

ABSTRACTS

Neurophysiological Basics for Brain-Machine Interface: Motor, Sensory, and Cognitive Rehabilitation and Limitation

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Decades of research have improved the brain-computer interface to allow people with severe disabilities to communicate their thoughts through recorded electroencephalographic signals along the scalp non-invasively. Recently, brain-machine interface based on neuroprosthetics for motor function has been inspired by successful demonstrations of controlling movement of computer cursors or even actual robots to perform meaningful tasks of feeding by control commands converted from cortical neuron activities from implanted intra-cortical electrode arrays. There are also active research efforts to pursue neuroprosthetic systems for recovery and enhancing sensory and cognitive functions.

In this lecture we will briefly review the techniques and neurophysiological basis of brain-machine interface based approaches for motor, sensory and cognitive function recovery and improvement. Finally, we will start a discussion on limitations and future directions of the field of BMI-based nueroprosthetics.

Consolidation of Prosthetic Motor Skill in Primates

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Research in Brain-Machine Interfaces (BMIs) has led to demonstrations of rodents, non-human primates and humans controlling prosthetic devices in real-time through modulation of neural signals. In particular, cortical BMI studies have shown that improvements in performance require learning and are associated with changes in neuronal tuning properties.

As these studies incorporated variable ensembles of neurons from day to day, and required daily modifications to the transform of cortical activity into motor output, little is known about long-term consolidation of prosthetic motor skill. Here we demonstrate consolidation, defined as motor skill that is retained, readily recalled and resistant to interference, in two macaque monkeys performing a center-out reaching task using a brain-controlled computer cursor under visual feedback. When a fixed transform was applied to stable recordings from an ensemble of primary motor cortex (M1) neurons across days, there was dramatic long-term consolidation of prosthetic motor skill.

This process created a directional tuning map for prosthetic function that was stable across days. Surprisingly the same set of neurons could encode a second motor map without interference with the first map. In contrast, daily modification of the transform, in a manner similar to past studies, resulted in variable performance and an unstable motor map. Taken together, our results demonstrate that the primate brain can achieve skilled control of a neuroprosthetic device through consolidation of a motor memory.

BCI-based Robotic Rehabilitation for Stroke

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Stroke is the third leading cause of death and the leading cause of severe disabilities in the developed world. Stroke causes neurological damage to certain portions of the brain, and surviving portions of the brain are capable of altering functional activity in a vicarious manner to provide a substrate for recovery. Current research is directed at understanding how this neuroplasticity phenomenon may be modulated to develop more effective therapeutic interventions such as neurorehabilitation for stroke. Robotic neurorehabilitation is motivated by alleviating the labor-intensive aspects of physical rehabilitation by a human therapist and by enabling novel modes of exercise not currently available. Current studies have shown that robotic neurorehabilitation helps improve motor recovery of chronic stroke patients.

Brain-Computer Interface (BCI) is a communication system that directly translates brain signals into commands for controlling an external device, which bypasses the normal motor output pathways. The brain signals can be acquired by scalp-recorded electroencephalogram (EEG) non-invasively from a subject. Studies have shown that distinct mental processes such as Event-Related Desynchronization or Synchronization (ERD/ERS) are detectable from EEG measurements for both real and imagined motor movements in both healthy subjects and stroke patients. Studies have also shown that it was useful for stroke patients to perform motor imagery during their rehabilitation exercises, but direct use of motor imagery based BCI for stroke rehabilitation was not intensively studied and tested in the clinical setting until recent years.

It is hypothesized that a motor imagery based BCI could provide an effective guide (through visual feedback) for a stroke patient while a robot provides useful sensory feedback. Hence, the synergy between BCI in the detection of motor intent from stroke patients and current robotic neurorehabilitation is promising. We started a clinical study on stroke rehabilitation with a BCI-controlled robotic system. This system enables stroke patients to make use their motor imagery to relearn motor control and improve their cognitive capacities at the same time. The clinical protocol and results will be discussed in detail.

BCIs Based on the Detection of High Gamma Oscillation in ECoG and EEG

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Brain-computer interface (BCI) technology augments the human capability to interact with the environment by directly linking the brain to artificial devices. In the recent past, BCIs provided simple 1D control in order to select targets or to trigger pre-defined motion sequences. Today, users have on-demand access to assistive robotic devices, Virtual Reality and to standard software applications such as Internet browsers or Google Earth. These accomplishments, together with technological and neuroscientific advancements have lead to more ambitious goals, e.g. the restoration of lost motor or sensory function. Such goals are within reach with invasive recording technologies. The electrocorticogram (ECoG), usually obtained from the brain surface in epilepsy patients, has high spatio-temporal resolution and higher signal-to-noise ratio compared to the non-invasive electroencephalogram (EEG). In fact, our latest results demonstrate that contralateral and ipsilateral finger movements can be accurately classified from high gamma (70-120 Hz) ECoG oscillations recorded from a single hemisphere. These findings have important implications for neurorehabilitation, suggesting, in particular, the possibility of regaining ipsilateral movement control using signals from an intact hemisphere after damage to the other hemisphere.

The non-invasive EEG, however, still plays the most important role for practical applications. The non-stationarity and inherent variability of EEG require time consuming training and mutual adaptation of both, the human brain and the machine. Ideally we aim to achieve the fidelity of ECoG with non-invasive techniques. Inverse mapping techniques can provide some amount of spatial unmixing of EEG signals and thus produce ECoG-like signals. Using these techniques, we demonstrate that mapped EEG can provide BCI signals similar to ECoG. We identify two control parameters in the high gamma frequency range in EEG: spatially localized power increases and bihemispheric phase-locking.

Non-Invasive Brain Controlled Robots

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The idea of moving robots or prosthetic devices not by manual control, but by mere "thinking" (i.e., the brain activity of human subjects) has fascinated researchers for the last 30 years, but it is only now that first experiments have shown the possibility to do so. Such a kind of brain-computer interface (BCI) is a natural way to augment human capabilities by providing a new interaction link with the outside world and is particularly relevant as an aid for physically disabled people. Key elements for a successful BCI are real-time feedback and training, of both the subject and the classifier embedded into the BCI.

In this talk I will review our work on non-invasive asynchronous BCI, with a focus on how brainwaves can be used to directly control robots. Most of the hope for such a possibility comes from invasive approaches that provide detailed single neuron activity; however, it requires surgical implantation of microelectrodes in the brain. For humans, non-invasive systems based on electroencephalogram (EEG) signals are preferable but, until now, have been considered too poor and slow for controlling rapid and complex sequences of movements. Recently we have shown for the first time that online analysis of a few EEG channels, if used in combination with advanced robotics and machine learning techniques, is sufficient for humans to continuously control a mobile robot and a wheelchair. Finally, we discuss current research directions we are pursuing in order to improve the performance and robustness of our BCI system, especially for real-time control of brain-actuated robots. In particular, I'll mention work on recognizing cognitive states that are crucial for interaction.

Non-Invasive Brain Controlled Robots

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Cognitive Integration of Prosthetic Devices: Is it Feasible?

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Technology has impacted human life in many different ways, but has followed a predictable evolutionary path characterized by the creation of artificial systems that have either been controlled explicitly by human limbs or have been made autonomous. The latest push has been characterized by the overwhelming use of digital computers and artificial intelligence/signal and pattern recognition algorithms. The research trend has progressively shifted towards autonomous platforms and has shown the difficulties of creating robust, truly intelligent behavior. In any case, machines are perceived as external and independent of our own bodies. The objective here is to revisit the human machine interface paradigm and provide broadband control of external machines directly through brain processes to capitalize both on the merits of biological information processing/intelligence and on man-made external devices that will enhance the reaction time, force, scale, physical locality, sensing of biological sensors and actuators.

We are at the brink of a revolutionary technology stage, where machines may be "cognitively integrated" in the human experience, manipulated and controlled through direct brain processes in virtually the same way as we see, walk or grab an external object. But unlike the current generation of brain machine interfaces, this is done through a dialogue that requires only that goals between the machine and the user coincide. The vision is a new kind of implanted prosthetics that senses intentional brain processes (e.g. moving an arm) and translates the spatio-temporal neural signals into models that control external devices. Through the perception action reward cycle the brain is made aware of the machine existence and actions, which will provide the basis to be considered a body extension. Several key technological and scientific developments will be discussed to implement this vision.

Cognitive Science and Human Factors Issues in Non-Manual Control Devices

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As display technologies become miniatured (and even embedded in the human), and as more of the tasks one does become computer-based, the traditional interface technologies that lie on keyboard input is beginning to shift to non-manual control devices (NMCD). It is however difficult to argue pre ante that an interaction device that is non-manual is an automated version of control (otherwise known as automatic control devices). I mention this so as to be clear about the intent of my presentation which argues for the challenges of NMCD rather than automatic control devices.

Historically, the development of computer interfaces has been a technology-driven phenomenon. The progress to tap into the human characteristics and interaction deficiencies led to the consideration of multi-

modal-multisensory interfaces (MMI).

Current progress in MMI have considered human speech, gesture, gaze, movement patterns, and other complex natural behaviors, which involve highly automatized skills that are not under full conscious control of the human operator. These are to some extent variants of NMCD. For example, in collaborative work environments, a large display may be fixed, but users move about the room, interacting with each other with small, mobile input devices. Thus, it can be surmised that most NMCD are sensory driven. Thus, cognitive science imperatives and human factors issues must be addressed so as to realize the full benefits of NMCD during human control of actions with these devices. This is necessary since sensory modalities span across the integration of human and system-level sensors such as visual (e.g. gaze), auditory (e.g., voice), haptic (e.g., hand movements, sign languages; lip reading, and the use of head movement for pointing). Obviously (although not completely), sensory information processing tends to be a cognitive task.

This paper will give a proposition on the cognitive science and human factors foundations of NMCD. The essential roles of multimodal, multisensory information integration, including the interpretation and use of such information for control of behaviors in task space, both spatially and temporally will be discussed, as well as the properties of different sensory modalities within NMCD components and the information content they carry.

In addition, this paper describes the important role that NMCD plays in information acquisition and processing in complex battlefield information systems. Specifically, the followings are addressed:

1. Interpretation of NMCD information at the semantic, syntactic, and pragmatic levels
of system abstraction.
2. Cognitive aspects of NMCD information processing and sensemaking, such as how
meaning of interacting multisensory information are derived, and how the derived information leads to understanding of dynamic contexts.
3. Human factors challenges in developing performance metrics, as well as the
ergonomics issues when NMCD mechanisms are embedded into the human operator.
4. Implications of NMCD to interface designs for military systems are discussed.

Non-Manual Visual Digest Networks

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Attention, understanding and abstraction are three key elements in our visual communication that we have taken for granted. These interconnected elements constitute a Visual Digest Network. Here we investigate the non-manual visual digest networks at three visual abstraction levels: gaze, object and word. The goal is to minimize the media footprint during visual communication while sustaining essential semantic data. The Attentive Video Network is designed to detect the operator's gaze and adjust the video resolution at the sensor side across the network. Our results show significant improvements in network bandwidth utilization. The Object Video Network is designed for mobile video and vehicle surveillance network applications, where faces and cars are detected. The multi-resolution profiles are configured for media according to the network footprint. The video is sent across the network with multiple resolutions and metadata; controlled by the bandwidth regulator. The results show that the video is able to be transmitted in the low-bandwidth conditions. Finally, the Word-Image two-way mapping network is designed for face reconstruction across the network. In this study, we assume the hidden layer between the facial features and referral expressive words contain 'control points' that can be articulated mathematically, visually and verbally. From our prototypes, we see the potential of the non-manual visual digest networks using gazing, talking and machine vision.

Integrating Hands-free Interface into 3D Virtual Reality Environments

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Summary
Navigating in the Virtual Reality (VR) scene[3,4] or playing a video game often accomplished by a transformation of human control over the VR or gaming device. This transformation is usually achieved by using a joystick or other hand-held controlled Systems14. Here we present an alternative and novel approach towards hands-free interface device for VR and videogames control, i.e. a sensor shirt[2]. It consists of 52-sensors woven inside the garment. This kind of interface with VR or other gaming devices, offers both portability and unobtrusive user movement in a VR environment.

This paper addresses the systems engineering aspects of the solution, and presents the initial results and future research directions. Participants navigated a VR scene using natural body movements that were detected by their wearable sensor shirt and then mapped to electrical control signals. The initial results are promising, and offer many opportunities for use in other applications.

Motivation
A 52-piezoresisitive sensor shirt, as reported in[2,6], was integrated with a fully immersive 3D VR environment. The sensor shirt behaved as a hands-free input device by detecting and then translating body movements into electrical control signals. This preliminary setup can be used for applications in multimedia and animation, motion tracking, robot-aided rehabilitation[1] and video game development. The proposed system is likely to cut labor costs as discussed in[3]. In the area of rehabilitation, the sensor shirt is easy to deploy and affords the patient comfort whilst navigating in a VR environment. Other alternatives require specific seating positions and recalibration procedures after short intervals[5]. A great advantage of the system is related to the high number of sensors: the redundancy in the sensor set makes possible to obtain the same control pattern with different body motions and lets the user choose which is the control scheme he prefers (i.e. the body motion patterns used to perform a certain action in the VR scene). By exploiting this concept, the control scheme will be adapted and personalized to the user.

Results
This article describes a novel method for navigating in a VR environment using smart sensing garment technologies. A wearable multi-sensor shirt that can detect upper body (wrist, elbow and shoulder) movements, was custom built to generate electrical control signals from residual movements. A combination of VR and signal processing methods were used to develop an effective body-machine interface to perform tasks. The sensor shirt was worn by a participant shows the front side of the sensor shirt), and the analogue signals originated from the shirt were converted into digital signals by a National Instruments analogue-to-digital converter. The digital output was read in Matlab Realtime Windows Target and the processed signals were sent as unified datagram protocol (UDP) packets to the VR software. Following a calibration phase and an initial training phase in the VR environment the user was capable of learning how to move in the VR scene. From an initial starting point in the VR scene, the control signals generated by the participant's movements were used to move the participant in VR. The sensor shirt was used with the VR system continuously for one hour without recalibration. Error measurements were calculated in the shoulder sensors outputs after 20 minute and 60 minute intervals. The results show the complete stability of the system (for at least an hour without recalibration), ease of deployment and comfort.

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Virtual Reality Feedback to Target Cortical Remapping

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Though the traditional human-computer interface (HCI) field focuses on extracting usable neural signals to control a computer device, it is equally important to understand how interacting with a computer device affects neural activity. This issue relates to a longstanding challenge in rehabilitation; that is whether and how clinicians can tailor technology to facilitate cortical reorganization in select brain regions of patients. We present data demonstrating that visual feedback illusions in Virtual Reality (VR) that are time-locked to actual movement can be a potent signal to the motor.

We asked three healthy subjects and two patients who have had a stroke more than six months ago, to perform a simple finger sequence (index-middle-ring pinky) with their dominant right hand (healthy subjects) or their unaffected hand (patients). During the task, we simultaneously acquired brain activation using functional MRI (fMRI) and hand kinematics (using an MRI-compatible data glove).

Hand motion animated either an ipsilateral (corresponding) or contralateral (mirrored) virtual hand model. In a visual feedback control condition, the virtual hand models were replaced with nonanthropomorphic ellipsoids. To also understand if brain activation would depend on training, the patients performed this task over three sessions, with a period of intense VR-based rehabilitation between the second and third fMRI session.

In the healthy subjects, the virtual mirrored feedback led to significant activation of the motor cortex ipsilateral to the moving hand. In the patients, no significant activation was noted in motor or premotor areas in first two baseline sessions. However, increased activation in the ipsilesional motor cortex occurred in the third session, despite the absence of active involvement of the ipsilesional motor cortex in this condition.

The contralesional motor cortex was also recruited in this condition (though the activation was weaker); activation which was not attributed to the movement of the hand since the control condition which had equivalent movement was subtracted from this contrast. In summary, our data suggest that virtual mirrored visual feedback may have had a facilitatory effect, which is amplified in patients after training in VR. These findings may have important implications for the development of novel therapies in the acute phase, when paresis and the potential for neural remapping are greatest.

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HUMAN-MACHINE VISUAL DIGEST

Yang Cai[1], Guillaume Milcent[1] and Rafael Franco[1]

Human vision is an information digest process in which attention, understanding and abstraction are three key elements. In this paper, we present an architecture of the human-machine visual digest system at two visual abstraction levels–gaze and object. By combining human vision and machine vision, we aim to minimize the media footprint during visual communication while sustaining essential semantic data. The system is designed to detect the operator's gaze and adjust the video resolution at the sensor side across the network. Our results show significant improvements in network bandwidth utilization. The machine vision system is also designed for mobile video network applications, where faces are detected. The multi-resolution profiles are configured for media according to the network footprint. The video is sent across the network with multiple resolutions and metadata, controlled by the bandwidth regulator. The results show that the video is able to be transmitted in the low-bandwidth conditions. By combining attention detection and pattern recognition, human and machines can interact at understanding and abstraction level.

Keywords: Attention, Video, Multiple Resolutions, Bandwidth, Semantic Network

Introduction

To our eyes, information is often redundant. We only pay attention to a very small portion of the information around us (Arnham, 1969). We often omit details by using diagrams, gestures, signs, symbols, icons, thumbnails, and words to represent complex images. This abstraction process is called a "visual digest," which enables us to communicate in minimal means. A visual digest is not the same as an image compression that is context-independent. Rather, it is based upon understanding of the context. Visual digest is abstract in order to reserve the structure, dynamics or interaction but still in a visual form. Arnham calls it representational abstraction (Cai, 2003).

Attention, understanding and abstraction are three key elements in our visual communication that we have taken for granted. These interconnected elements constitute a "visual digest network."

Human vision is driven by attention (Allport, 1993). The center of our gaze where we are looking, called the fovea, has the highest possible visual acuity. However, in the peripheral visual field, we have surprisingly low visual acuity. We are not conscious of this because we instinctively direct our center of gaze to where we are looking. Our foveal vision is optimized for fine details, and our peripheral vision is optimized for coarser information.

Human attention is guided by purpose. Humans selectively look at objects that are interesting. Furthermore, humans anticipate objects that are familiar. Cognition psychologist Yarbus (1967) uses eye tracking systems to study the gazing path of the human visual information process. He demonstrates that the gaze pathways are different if the viewers are asked different questions about a painting. To understand the imagery data, viewers have to know the name of objects and the relationships among them.

Given a method to detect gaze and objects, how do we encode our visual information in multiple resolutions to minimize the communication load and maximize the efficiency for information retrieving? Figure 1 illustrates the architecture of a visual digest network.

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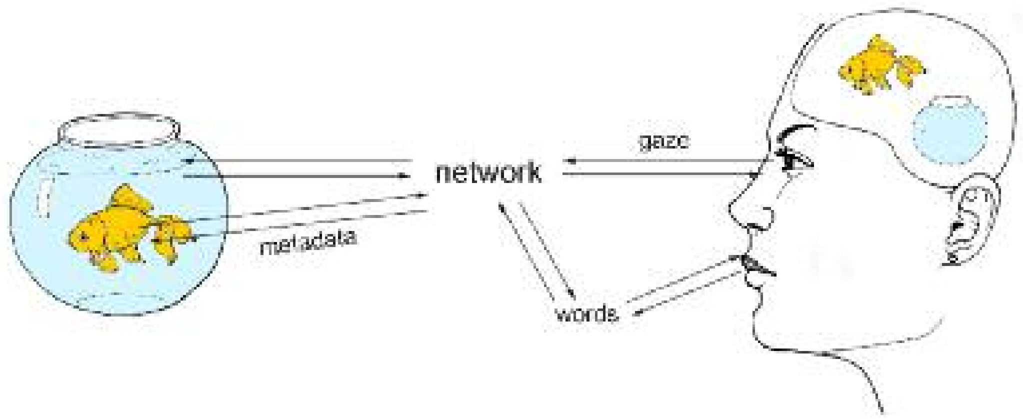

Figure 1. Overview of the semantic visual search in a network.

The objective of this paper is to prototype these two elements with computers to prove that visual communication flow can be improved by encoding multi-resolution data in the media for display and objects. This study will also demonstrate applications for real-world problems, such as video network system design. For example, if a network system can sense the user's attention and only pass the high-resolution video via embedded metadata, then it would save an extremely large amount of network traffic. For a digital video network, this is significant because we can use the rest of the network bandwidth to add more devices without changing the architecture of the existing systems.

Attentive Video Network

The foveal area has only about a three-degree visual angle, which is very tiny compared to the peripheral visual field. Economically, we only need to display a significantly small region in acuity, if a system can track a viewer's eye movement. In light of this, Gaze-Contingent Displays (GCDs) have been developed to degrade the level of detail (LOD) of peripheral image regions in order to reduce computational workload during image transmission, retrieval, or display. It intends to match the amount of information displayed against the human visual processing capacity through real-time eye movement sensing (Duchowski, 2004).

To realize a GCD system, we degenerate the spatial resolution (pixels), temporal resolution (frame rate) and color depth (number of colors) for the peripheral or unattended region to reduce significantly impairing network performance. This is attractive for transferring videos over a low-bandwidth network. Gaze-based image compression is developed to trade the LOD for network bandwidth with encoded images at the super-pixel level (Kortum, 1996; Geisler, 1998). However, to recompose a multi-resolution image is challenging. In addition, to track gaze positions at the super-pixel level needs a precise eye tracking device with a well-calibrated, restricted dynamic observation range.

Attentive user interfaces (AUIs) use gaze to control screen objects or physical devices other than the keyboard or mouse. These interfaces require less precision in eye tracking. Typical cases include so-called eye typing for disabled users (Majaranta, 2002) and gaze remote controller for television sets and lights (Shell, 2003). In extreme cases, AUI can be simplified to a binary state detection–attentive, or not attentive to the display, which is inexpensive and tolerant to the user's head movements. For example, the eyeCONTACT system can monitor whether a user is watching the display. The video would be pulsed if the user is away. The coarse resolution control enables economically low resolution and non-calibrated eye tracking (Gibbens, 1991).

Human Visual Information Processing Bandwidth

In this study, we design an attentive user interface for a multiple video display system that uses minimal network bandwidth. Our approach has two unique features: first, we use gaze to select video channels and zoom to the selected video, which enables a ubiquitous display control. Second, we optimize the dynamics of the bandwidth changing in a network during the multimodal operation, where the network traffic is a function of the visual attention. Given n camera live video channels with adjustable resolutions high and low that are arranged on a monitor screen, we want to find the minimal network traffic as the computer detects which video channel is selected.

What is the human visual information processing bandwidth? It contains two parts—temporal bandwidth and spatial bandwidth. Temporal bandwidth is well-known as the limit of 30 frames per second. For the spatial bandwidth, it is more complicated because of we have two kinds of sensors (rods and cones), blank spots and optical distortions. We can only do a rough estimation. Here, we assume that human acute vision distribution is a Gaussian Function, where the foveal angle, screen size, and viewing distance bare the key variables. For a screen 84 cm diagonally-wide, resolution 1920 x 1080 pixels, at 30 cm view distance, it is found that only 20% to 25% of the pixels are effective to a viewer.

However, we cannot simply remove the pixels in the peripheral area because its motion perception is important to surveillance and must be enhanced for the overall vision. When an object moves on the far retinal edge, an immediate reflex swings the eyes in a direction which aligns the moving object with the fovea. Closer in, the peripheral retinal tissue can "see" movement, but there is no object recognition. When movement stops, the object becomes invisible. According to this biological phenomenon, the frame rate cannot be reduced without a loss in the level of perception. Therefore, we propose a system which reduces the resolution in the peripheral area but keeps a high frame rate for vigilance.

Video Network Bandwidth Control

For wireless networks the bandwidth appears to be the limiting factor and displaying multiple digital videos with high resolution, high frame rate and high quality on a local wireless network is a rather non-trivial task. Adaptive bandwidth management has been studied such as queueing, input rate regulation, allocation, filtered input rate, etc. (Sidi, 1989; Erin, 2004; Weiman, 1990). However, the bandwidth problem still exists in many large wired video surveillance systems that contain hundreds of cameras. An attention and context contingent interface is desirable to manage the network flow on demand by matching the network bandwidth with the human visual information processing bandwidth.

The video network bandwidth is a function of the number of cameras, video size, compression ratio, video resolution, frame rate and scene complexity. Typically, for a video in a resolution of 640x480 pixels with low compression 10%, max frame rate (30fps) and four cameras, the bandwidth required is estimated 36.4 mbit/sec. That is the reason why a system with more than 12 cameras overtakes the capacity of traditional

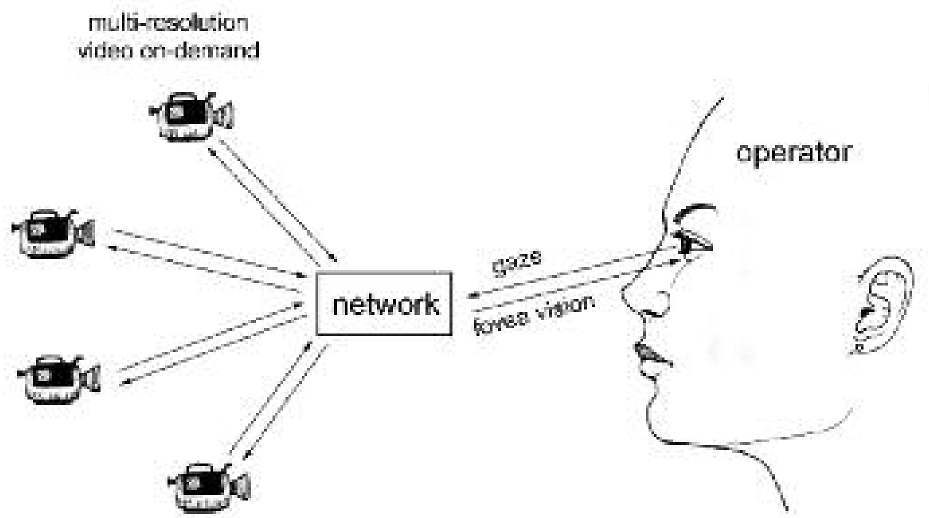

Figure 2. The attentive video network where cameras' resolution is controlled by gazing.

Attentive Video Network with Multi-Resolution
The experimental system contains four network cameras on a local network. Each camera is enabled to dynamically set resolutions as high (624x480) or low (320x 240). The monitor displays four video screens in a low resolution and the highlighted channel in the high resolution and large size.

The gaze detection software is programmed in C with the API from EyeTech (2007). Two infrared lights are mounted on the sides of the monitor. The camera can capture the eye gaze at 60 frames per second and the accuracy of three degrees. To avoid overreaction of the gaze detection, a timer is incorporated to avoid a windshield wiper effect. In this experiment, the operator uses his eyes to switch the video channels from a low resolution to a high resolution. The traffic monitor software records the real-time data flow. The video recorder stores the operator's verbal protocols and visual context on the screen.

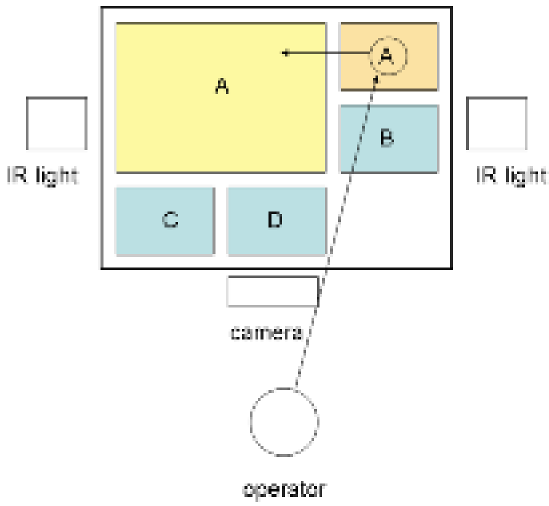

Figure 3. The screens A, B, C and D are in low-resolution.
When the operator gazes at screen A, it evolves to a high-resolution screen on the top left (yellow).

Network Dynamics
Four experiments were conducted to compare the network dynamics in different configurations: Fixed Switch, Dynamic Switch, and Evolved Switch.

• Fixed Switch. Fixed Switch has no network bandwidth at all. The network passes all the video channels and the display shows each channel in rotation at a fixed timer. Therefore, the network traffic is constant, which is typical in many commercial systems.

• Dynamic Switch. When the operator watches one of many channels that enlarged into a full screen mode, the network stops to pass the rest of video channels.

• Evolved Switch. When the operator watches one of the many channels at the peripheral vision screen set, the rest of the channels turn to low resolution.

These scenarios are tested with default static parameters–resolution (640x480) and compression (10%). As explained previously, the number of frame rate is maintained at 30 fps to guarantee a full movement perception.

Object Video Network
Object video is a context-aware media process that encodes the hierarchic 'meaning' of the content in the video instead of just the intensity or colors of pixels. Object video is based on the object detection and video metadata codec technologies. Given an image, to detect an object means to determine whether or not the vehicle is present, and, if present, to determine the locations and sizes of each object. By identifying and passing meaningful objects in the video, we may also minimize the risks of privacy and bulky data traffic over the wireless networks. For example, we may only transmit the suspected objects in the video.

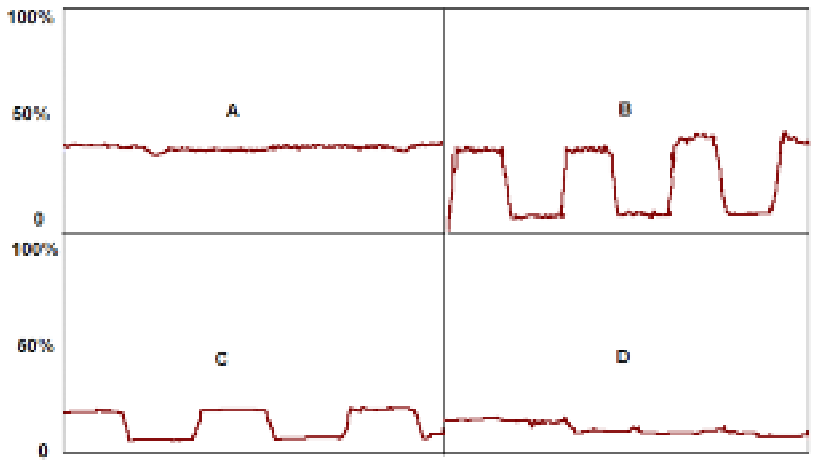

Figure 4. Network traffic status in four switching modes: (1) 38Mbt/s used for a static management, (2) 38Mbt/s–9Mbt/s for a basic dynamic switch, (3) 22Mbt/s – 8Mbt/s for an evolved switch, and (4) 22 Mbt/s - 10Mbt/s CMU dynamic control (100%=100Mbt/s).

Table 1
Comparison of the approaches in the study

Management	**Bandwidth average**	**Reduction**
Fixed Switch (timer)	38 Mb/s	0%
Dynamic Switch (human)	24 Mb/s	39%
Evolved Switch (timer)	16 Mb/s	57%
Evolved Switch (human)	10 Mb/s	67%

Object detection is a fundamental issue in computer vision. Since the pioneering work of Roberts (1965) in the early 60s, there has been tremendous progress in object recognition. Commonly adopted matching and recognition strategies have used trees search (Grimson, 1991) and object models (Gaston, 1984), the viewpoint consistency constraint (Lowe, 1987), attributed graph matching (Fan, 1989), the generalized Hough transform or pose clustering (Ballard, 1981; Grimson, 1990; Silberg, 1984), alignment (Ullman, 1991), and geometric hashing and invariants (Chen, 1993; Forsyth, 1991).

For object video, metadata is essential for multimedia information retrieving and the real-time scene recognition. MPEG-7 and MPEG-47 address metadata structures that enable encoding of multimedia objects inside the video. They use XML to store metadata, and can be attached to time code in order to tag particular events, or synchronize lyrics to a song, for example. At the Kodak Research Center (Luo, 2006) researchers add intrinsic data of a camera such as focal length, flash light state and exposure time, to the imagery metadata. The study shows that the combination of the computer image analysis and intrinsic metadata can help to classify the photos, for example, outdoor scenes or indoor scenes, at the rate of 93%. This enables a drastically sped up information retrieval process.

Quality of Service-Aware Encoding

Here, we investigate the feedback from network bandwidth to object video. By assigning a set of profiles of the metadata according to their network footprint we can improve the network quality of service (QoS) accordingly: 1) at full bandwidth condition: metadata and full resolution image, 2) at reduced bandwidth condition: target in high-resolution and back-ground in low-resolution, plus metadata, and 3) at lowest bandwidth condition: metadata only.

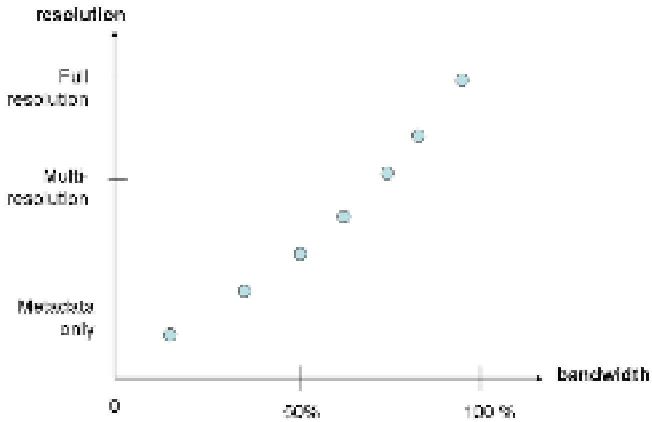

Figure 5. Object video profiles according to network bandwidth status.

In many cases, sending the metadata should be enough for daily operations because normally there are not enough human operators to watch the constant real-time videos. The main function of the onboard video has been for recording rather than real-time detection. Our technology enables real-time detection without adding too much burden to the system.

Hybrid Visual Digest

Human vision is powerful in discovering interesting or anomalous objects. However, our vision easily becomes fatigued. On the other hand, machine vision can keep going around the clock. However, the reliability of machine vision is not always perfect, especially when new objects enter the scene. It is desirable to combine human vision with machine vision in one platform. In this case, we only combine the high-resolution areas. Assume **H** is the interested areas from the human vision and **M** is the interested areas from the machine vision, the hybrid area **R** is:

$$R = H \bigcup M$$

In training mode, the system examines the non-overlapping areas **O** between **H** and **M** as a feedback input to machine vision. The objective is to maximize the overlapping areas **R** and minimize the differences **O**.

$$O = H \bigcap M$$

Users can control the weight between human vision and machine vision. For example, in the operation mode, users can set human vision as the highest priority that can override the machine vision. On the other hand, while the human operator is not available, the machine vision may take over the visual digest process.

Augmented Mobile Video

Transmitting videos across a cellular phone network is a challenge because of the very limited bandwidth and the noisy radio field. In this case, we assume that the region of a human face in the video is smaller than the region of the background. We may save bandwidth by transmitting the faces in a high resolution and the background in a low resolution. Figure 6 illustrates the augmented mobile video concept.

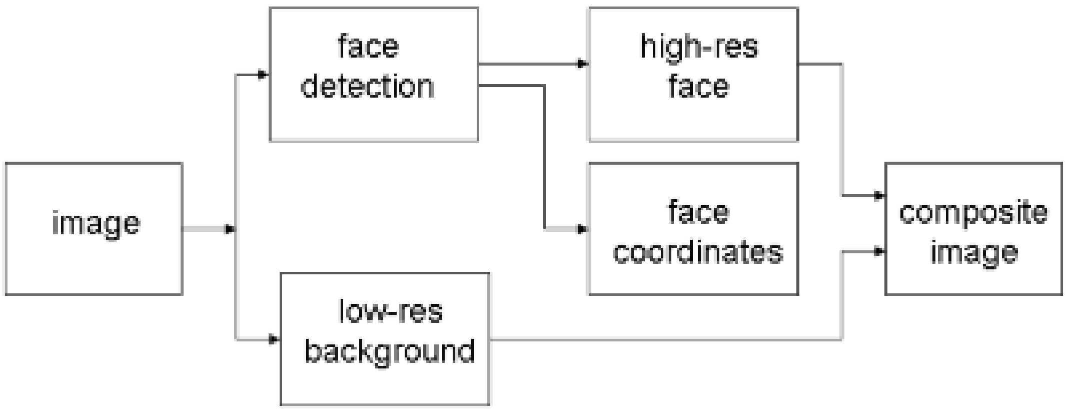

Figure 6. Augmented video with metadata for multi-resolution video transmission.

We use the Haar Transformation (Haar, 1910) to detect simple facial features, such as eyes, noses, mouths and then we cascade the classifiers to determine whether those features warrant a face. For example, eyes are supposed to be above the nose and mouth. The cascaded classifiers are trained by samples with a weight voting model (Viola, 2001).. The performance of a trained classifier strongly depends upon the quality of the database used. For example, if the training samples only contain the front of faces, then the classifiers can only recognize frontal faces. Nevertheless, this method yields fast performance for real-time applications such as mobile video streaming. It works well with a simple and uniform background. However, its recognition rate becomes worse if the background is complex. For example, the model may mistake some textures for human facial features.

Figure 7. Real-time face detection on Nokia phone N70 with multi-resolution encoded images transferred over the Bluetooth. Bandwidth reduction from 220K (bmp) or 62 K (jpeg) to 2K.

We built the real-time face feature detection on the Nokia phone N70 with multi-resolution encoded images transferred over Bluetooth. Bandwidth is reduced from 220K (bmp) or 62 K (jpeg) to 2K. From our preliminary study, we found that the metadata-based video compress can save the bandwidth up to 88%. For metadata-only transmission, the saving could be on orders of two to three times the magnitude. In security, "less-is-more" can be critical for detecting the real target or rapidly retrieving the video records. With the metadata, investigators can easily find segments and locate frames they are interested in.

Conclusions

In this paper, we have investigated the conceptual design of Visual Digest Network at three visual abstraction levels–gaze, object and word. Our goal is to minimize the media footprint during visual communication while sustaining essential semantic data.

The Attentive Video Network is designed to detect the operator's gaze and adjust the video resolution at the sensor side across the network. The results show significant improvement of the network bandwidth. However, the gaze detection system is rather restricted. It doesn't work within a multi-operator environment.

The Object Video Network is designed for mobile video and vehicle surveillance applications, where faces and cars are detected by wavelets, motion segmentation and local features. The multi-resolution profiles are configured for the media according to the network footprint. The video is sent across the network with multiple resolutions and metadata, controlled by the bandwidth regulator. The results show that the video is able to be transmitted in much worse conditions. However, the metadata and the video transmission protocol have not been standardized yet. It is important to share the object detection modules and metadata structures across various industries.

Today, we have so much data but not enough people or bandwidth. Image and video collections grow at a rate that exceeds the capacity of networks and human attention. In real-time surveillance systems, over a terabyte per hour are transmitted for only a small number of platforms and sensors. We believe that the visual digest network is one of the feasible solutions.

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BRAIN-COMPUTER INTERFACE RESEARCH AT THE UNIVERSITY OF WASHINGTON: EEG- AND ECOG-BASED PARADIGMS

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The development of practical brain-computer interfaces (BCI) is proceeding rapidly and devices can now often provide control to select targets or to trigger pre-defined motion sequences. To move toward the eventual goals of restoring lost sensorimotor function, information transfer rates will need to increase. Information transfer can be improved at the signal and application end, and we provide several examples where our laboratory has addressed both issues.

In particular, we have implemented P300 control of an autonomous humanoid robot and EEG-based motor imagery control of the Google Earth software. An anatomically correct test bed for a human hand model provides another example where applications are specifically designed to maximize the utility of a readily available control signal. In parallel, we seek signals that can provide improved information and fidelity of signal, including signals obtained from direct recording of the human cortical surface. The high-frequency signals seen at this level show promise for practical BCI applications, such as the use of contralateral and ipsilateral movement signals from the motor cortex, and, once identified by invasive means, may actually be detectable in non-invasive EEG recordings. These combined strategies may improve BCI development.

Keywords: Brain-Computer Interface (BCI), Electroencephalogram (EEG), Electrocorticogram (ECoG), Neurobotics, Motor control

Introduction

Brain-Computer Interface (BCI) technologies enable the establishment of a direct connection between the human brain and artificial devices. Actual movements are no longer necessary to interact with the environment. Instead, actions are encoded into predefined brain patterns that the BCI can detect and translate in real-time. The motivation for the development of such direct interaction channels is to reestablish, at least to some extent, communication capabilities of physically disabled individuals. These include individuals suffering from degenerative neurological diseases such as amyotrophic lateral sclerosis (ALS), individuals with spinal cord injury or survivors of a stroke.

Until recently, typical BCIs provided simple 1D control in order to select targets on a computer screen or to trigger predefined motion sequences (Birbaumer et al., 1999, Wolpaw et al., 2003, Pfurtscheller et al., 2003, Müller-Putz et al., 2005). Today, users can use BCIs for on-demand access to assistive robotic devices, Virtual Reality (VR) and standard software applications (Galán et al., 2008, Leeb et al., 2007, Bensch et al., 2007, Scherer et al., 2007). These accomplishments, together with technological advancements in neuroscience (Moritz et al., 2008, Ganguly et al., 2009) have lead to more ambitious goals, such as the restoration of lost motor or sensory function. Currently, the information transfer rates are still low compared to manual control (generally less than 30 bits min-1), but have risen to a level

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at which BCI technology may eventually become useful for able-bodied individuals, with potential applications in working environments where movements are constrained, such as zero gravity environments (Rossini et al., 2009).

Here, we review some recent work in the field conducted at the University of Washington in Seattle. The review is divided into three parts. The first part presents two applications based on the non-invasive electroencephalogram (EEG)–P300-based control of an autonomous humanoid robot (Bell et al., 2008) and motor imagery-based control of the Google Earth software (Scherer et al., 2007).

The second part of the paper deals with the restoration of hand motor control. The electrocorticogram (ECoG), usually obtained from the brain surface in epilepsy patients, has high temporal resolution, spatial specificity and a better signal-to-noise ratio compared to the non-invasive EEG. We have found that contralateral and ipsilateral finger movements can be accurately classified from high gamma ECoG oscillations recorded from a single hemisphere (Scherer et al., 2009). Human hand dexterity is achieved partly by direct neural control of movements and partly by the biomechanics of the system. In order to identify the most meaningful neural motor commands and to discover neuromuscular details of the human hand that allow dexterous multi-finger movements, we are working on the development of an anatomically correct robotic hand system, the ACT hand (Wilkinson et al., 2003).

Invasive ECoG technology poses a considerably higher medical risk compared to the noninvasive EEG and is currently only employed for medical reasons other than BCI, such as pre-surgical epilepsy monitoring. Inverse mapping techniques allow mapping of activity recorded by EEG on the scalp to the cortex, thus producing ECoG-like signals non-invasively. Using these techniques, in the last part of this paper we show that mapped EEG can provide signals similar to ECoG. We identify two control parameters in the high gamma frequency range in EEG–spatially localized power increases and bihemispheric phase-locking (Darvas et al., 2010).

Non-invasive EEG-based applications

One issue of current BCI systems is the low information transfer rate (ITR). The low bandwidth makes direct control of devices such as wheelchairs or applications such as word processors difficult. Even if it is possible, direct control of a device on a millisecond or even seconds time scale can be tedious. Goal-oriented control is one way of overcoming this problem. Instead of directly operating a motorized wheelchair, for example, the user only needs to specify the final destination. At any given moment, however, the user has to have the ability to interact with the device and to take over control–in this case, to select a new destination. Ideally, for practical issues, one wants to have both modes, direct and goal-oriented control. We describe below two applications of goal-oriented control. Other researchers have explored similar approaches (Galán et al., 2008).

Control of a humanoid robot

In (Bell et al., 2008), we demonstrated that EEG-based goal-directed control of a partially autonomous humanoid robot allows sophisticated interaction with the environment. The experiment simulated the scenario in which the disabled BCI user needs physical interaction with objects in their environment. The humanoid robot acts as a helper robot that mediates this physical interaction. For example, if the user is thirsty and would like some water, the helper robot could be commanded to get a cup filled with water from the kitchen. To be able to autonomously perform this task, the robot requires prior knowledge of the environment and some amount of autonomy–it has to be familiar with the environment, know the location of cups and water, and be able to manipulate objects.

In our experiment the humanoid had to deal with several of these tasks. The diagram in Figure 1(a) illustrates the experimental setup. First, the robot autonomously walks from a starting position towards a table with a red object and a green object. To be able to identify objects in the experimental arena, the robot was equipped with cameras and computer vision. The user receives a live feed from the robot's cameras, thereby immersing the user in the robot's environment and allowing the user to issue commands based on relevant image features (see below). For spatial orientation in the arena, the robot also relies on an overhead camera.

When the objects are within reach, the robot transmits the segmented images of the two objects it sees and asks the user whether to pick-up the red or green cube. The selection is made by the user based solely on EEG signals as described below. After picking-up the object selected by the user, the humanoid asks the user which location, out of a set of known locations, to bring the selected object to (in the experiment, either the table on the left or the table on the right side of the arena). This selection of the destination is again made by the user using EEG. Finally, the robot walks to the destination selected by the user and places the object on the table at the selected location. Apart from the BCI-based user high-level commands, the humanoid autonomously moves within the arena and possesses the ability to pick up and drop off objects. Behaviors such as walking and picking up objects were taught to the humanoid through imitation learning from human motion capture (Chalodhorn et al., 2007, Grimes et al., 2008).

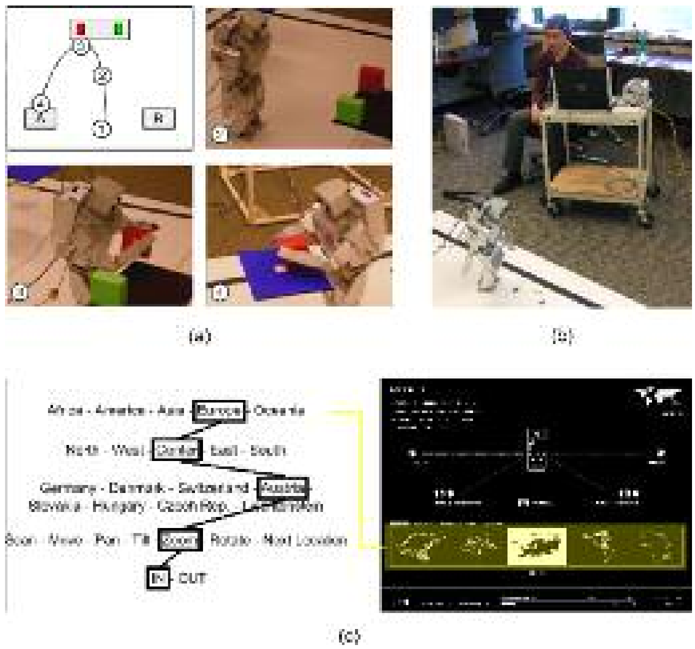

Figure 1. (a) P300-based humanoid robot experiment. Starting from position (1), the humanoid had the task of finding objects of interest in the arena (2), pick up the desired object (red or green cube, 3) and place it on the selected desk (A or B, 4). At (2) and (3) interaction with the user was initiated. (Modified from Bell et al. (2008)). (b) Self-paced humanoid control with sensorimotor BCI. (c) Interface for the control of Google Earth. The scheme on the left hand side illustrates the hierarchical arrangement (levels) of countries and the commands for the virtual camera. The example shows the selections required to move the virtual camera over Austria and to zoom in. The screen shot on the left hand side shows the graphical user interface (GUI). The Gui is subdivided into two parts. The upper part provides feedback to the user on the currently detected mental activity and the lower part shows icons representing the available options. The feedback cursor can be used to select commands such as 'Select' to select the highlighted option, 'Back' to go back to the previous level and 'Scroll' to browse the available options. Modified from Scherer et al., (2007) .

The BCI for the above task was based on the detection of the P300 component of the visual evoked potential. The P300 is a potential shift occurring about 300 ms after the user consciously attends to a changing visual stimulus. The visual feedback provided to the user in the above experiment were the segmented images of objects captured by the humanoid's camera. Each time the robot expects new instructions, the images of the possible choices (objects in the camera image or images of destination locations) are presented to the user. These images are scaled and arranged as a grid on the screen and the grid can be dynamically adapted depending on the segmentation of the image. To select the desired option, the user focuses his or her attention on the image of choice while the border of each image is flashed in random order. In this case, a red border was presented for 125 ms every 250 ms. In order to focus the user's attention, subjects were asked to count the number of flashes on the image of choice.

Thirty-two EEG channels were recorded form electrodes placed over the entire head according to the extended 10-20 system. A linear soft-margin classifier was used to classify the EEG that was spatially projected to enhance discrimination between event-related and non event-related EEG patterns (further details can be found in Bell et al., 2008). The performance of the BCI depends on the reliability of P300 detection. Usually, several flashes are required per choice to increase the robustness of classification. Our results, based on nine subjects, show that an accuracy of 95% can be achieved for discriminating between four classes.1 With the implemented rate of four flashes per second, the selection of one out of four options takes five seconds (ITR 24 bits min-1). Moreover, this performance can be achieved after only a few minutes of training.

The experiment described above was designed in such a way that the robot requested input from the user whenever new directions were needed. Consequently, the BCI was operated according to a cue-guided paradigm. To enable direct control, users have to have on-demand access to the BCI and be able to voluntarily initiate communication at any time. Thus, to enable self-paced communication, the

BCI needs to constantly analyze the user's ongoing brain activity, not only during predefined time periods. Our current work addresses this issue by combining P300 and oscillatory brain activity.

In general, event-related potentials (ERPs) such as the P300 are comparably easy to detect and the training period is short. However, external stimuli are needed to evoke the desired brain response. Event-related oscillations (EROs), on the other hand, can be induced voluntarily by the user. A common strategy to modulate for example sensorimotor rhythms is motor imagery, i.e., the kinesthetic imagination of movements. The detection of EROs in EEG, however, is difficult because of the phase jitter between the mental imagery and the induced changes in the rhythmic activity. Furthermore, it is difficult to deal with a large number of classes. Therefore, only two different mental tasks are typically employed for communication. Figure 1(b) shows a picture of such a motor imagery based self-paced humanoid control. In this preliminary experiment, the user performed foot motor imagery to voluntarily initiate and stop walking. Our ongoing work is focused on incorporating more classes of actions and integrating self-paced control with ERP-based commands for flexible and scalable humanoid control.

Control of the Google Earth application

In Scherer et al. (2007, 2008) we proposed a self-paced three-class BCI. For EEG-based BCIs, especially for the self-paced operation mode, the detection and reduction of noise and artifacts is extremely important. Artifacts are signals that do not originate from the brain, but which may influence the BCI output. The most common artifacts generated by the user are caused by muscle movements (electromyogram, EMG) and eye movements (electrooculogram, EOG). Both artifacts have a wide frequency range; EOG has a maximum below four Hz and EMG at frequencies higher than 30 Hz. The typical frequency range of sensorimotor BCIs is 8-30 Hz, and thus reactive components are close to the range of the artifacts. We used regression to reduce EOG artifacts (Schlögl et al., 2007) and inverse filtering to detect EMG activity (Lopes da Silva et al., 1977). Furthermore, to reduce the complexity of the BCI only three bipolar EEG channels, recoded from six electrodes, were used.

To achieve self-paced operation, in a first step, the user performed cue-guided three-class motor imagery feedback training. The imagery tasks included left hand, right hand and either foot or tongue imagery. To provide feedback, subject-specific oscillatory patterns, resulting in a number of band power features for each EEG channel, were identified and a committee of Fisher's linear discriminant analysis (LDA) hyperplane classifiers (Duda et al., 2000) were trained for classification. Cue-guided training was performed until the three-class classification accuracy was satisfactory (75%). During this training, not only were the parameters of the BCI adapted to the user's brain activity, but also the brain learned to reliably generate the patterns. At this point, an additional LDA classifier was trained to detect any of the three stabilized motor imagery patterns, such as to detect general motor imagery activity, in the ongoing EEG. For self-paced operation we simply combined the output of the different classifiers. Whenever motor imagery activity was detected by the individual LDA classifier, the LDA committee voting defined the BCI output signal.

Computing the performance of self-paced BCIs is difficult because the real intent of the user has to be assessed and correlated with the BCI output. Instead, we used a cue-guided paradigm with longer periods, where no motor imagery had to be performed, to evaluate the performance and three subjects participated in the experiment. After about five hours of training, the three-class classification accuracy was more than 80% with 17% false positive detections during non-imagery periods (Scherer et al., 2008). To give subjects the possibility to voluntarily initiate, hold and release motor imagery patterns, we also designed a game-like virtual environment (VE). The task was to navigate through the VE and collect items. For navigation in the VE, the three motor imagery patterns were translated as rotation to the left, rotation to the right and move forward. The only constraint was a time limit of three minutes for each experimental run. Users self-reported on satisfactory self-paced control.

Compared to standard BCI applications, the number of degrees of freedom and the number of available options required to achieve reasonable control are high for standard software applications. However, for specific applications, a useful performance can be achieved. To be able to use the three-class self-paced BCI to interact with the Google Earth virtual globe program, we designed a special graphical user interface (GUI, Scherer et al., 2007). Instead of selecting letters in order to type the name of a country, the countries were hierarchically grouped by continent and continental area. Thus, three selections were required to isolate the country of interest and to position Google Earth's virtual camera. See Figure 1(c), right plot. To visit the final location the fourth level allowed the direct manipulation of the virtual camera. A total number of 201 different options were available with the options including countries and modification of the camera position. The screen shot in Figure 1(c) shows the implemented GUI. The three imagery patterns were used to scroll through available options, to select the desired option and to undo the previous selection. After an additional training time of about 10 hours, one subject previously participating in the three-class self-paced experiment successfully operated Google Earth in front of a public audience. The average time to go from level one to level four was about 20 seconds.

Towards invasive neuroprosthetics

Self-paced EEG-based ERO-BCIs, together with functional electrical stimulation, can be used to restore hand function in individuals with spinal cord injury (Pfurtscheller et al., 2003, Müller-Putz et al., 2005). The low bandwidth and the noise, however, are currently limiting factors for the implementation of efficient neuroprosthetic control. Several groups, including ours, proposed the use of the invasive electrocoricogram (ECoG). ECoG signals are recorded from electrodes placed on the surface of the brain without penetrating the cortex. The signal amplitudes are up to 100 times higher than those of the EEG and usually a large number of electrodes (>64) are available. Since the signals are recorded directly from the surface of the cortex and each electrode records only neuronal signals directly beneath it, there are limited cross talk effects between electrodes. Thus, ECoG benefits not only from a higher signal-to-noise ratio but also provides high spatial specificity compared to the non-invasive EEG. A number of studies have successfully shown correlations between actual movements and oscillatory ECoG components (Blakely et al., 2009, Felton et al., 2007, Graimann et al., 2004, Hill et al., 2006, Miller et al., 2009, Pistohl et al., 2008, Schalk et al., 2008). Especially oscillations in the high gamma range–frequencies above 70 Hz–were found to provide characteristic signatures for motor execution and motor imagery. Being invasive, however, the availability of ECoG is usually limited.

Classification of ipsilateral and contralateral finger movements

Often neurological damage, such as an internal capsule stroke, leaves ipsilateral motor function preserved, while contralateral function is lost. In such cases it would be useful to obtain BCI control signals for both hands from one single hemisphere.

We addressed this issue and performed experiments with two neurosurgical patients who underwent a temporary placement of a subdural electrode array in order to localize the focus of epileptic seizures (Scherer et al., 2009). In both patients the electrode grid covered sensorimotor brain areas. ECoG was recorded while patients were performing cue-guided repetitive motion tasks of left or right thumb or index finger movement. The finger movement patterns were recorded using a data glove. Template brains with superimposed electrode grid positions are shown in Figure

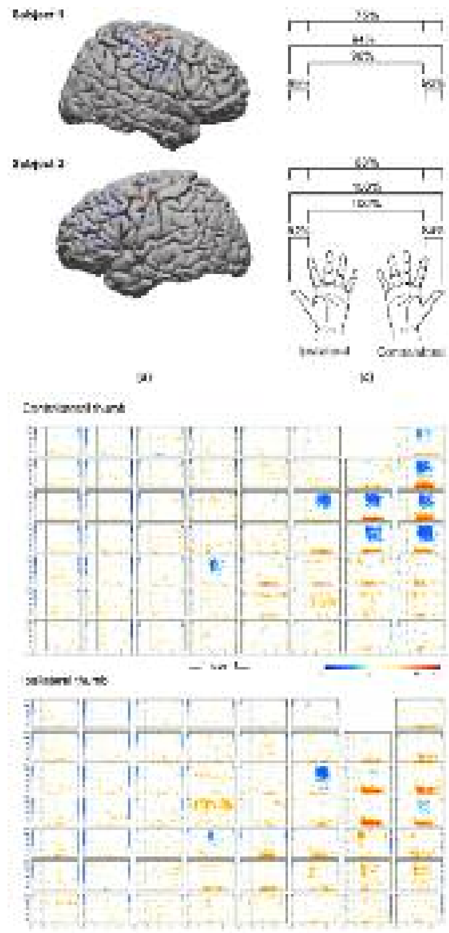

Figure 2. (a) Placement of the ECoG electrode grids for both subjects (56 and 64 channel grid). (b) Time-frequency plots of significant (alpha=0.01) power increase (red) and decrease (blu) for subject 2 during contralateral and ipsilateral thumb movements. The reference interval was placed from -0.75 to -0.25 prior to cue presentation. Modified from Scherer (2009). (c) Classification accuracies between different finger combinations.

2(a). The results of the time-frequency analysis confirmed the well documented phenomenon of a focal power increase in frequencies above 50 Hz and a widespread decrease in lower frequencies (8-40 Hz). Similar time-frequency activation patterns were induced during contralateral and ipsilateral movements. Surprisingly, the high frequency modulations during ipsilateral movement were more focused than those during contralateral movements. Figure 2(b) shows the time/frequency map of significant power changes as function of time for contralateral and ipsilateral thumb movement for one subject.

On average, the single-trial classification accuracy between either the two digits on the ipsilateral or contralateral hemisphere or between the same digits of the two hemispheres was 83.3% (using cross-validation). For classification, band power features estimated in the two standard frequency bands 8-40 Hz and 71-100 Hz (as proposed by Shenoy et al., 2008), were used. To identify the most reactive electrodes, each channel was analyzed individually. After identifying subject-specific frequency bands (from a range of 6 - 125 Hz) the average classification accuracy increased up to 89%. Figure 2(c) summarizes the accuracy achieved by two and four digit classification for both subjects. The average classification accuracy between the four movements was about 78% with a random level at around 33%. The distinction sensitive learning vector quantization (DSLVQ), (Pregenzer et al., 1999), method was used for classification and for the identification of the most relevant spectral components. The spectral power was estimated from one-second time intervals.

The results of this study confirm the usefulness of ECoG as input signal for the BCI and demonstrate that signals recorded from one hemisphere can be used to decode contralateral and ipsilateral finger movements. In the presented study we focused on the spectrum and by using one-second segments to estimate the power, we neglected the short-term temporal dynamic of the oscillatory activity. If this were to be taken into account as well, we would expect an increase of the classification performance.

For a better translation of the spatial-spectral-temporal oscillatory activity patterns that are required to achieve direct control of a neural prosthesis, it is important to understand the neural mechanisms that control the function of the human hand. To understand the neuromuscular details of the human hand that allow dexterous multi-finger movements, we aim for the development of the most anatomically correct robotic hand system.

The Anatomically Correct Testbed (ACT) robotic hand

Numerous anthropomorphic robotic hands have been developed with the goal to replicate human-level dexterity. However, none of the existing hands are able to go beyond gripping simple objects autonomously. Dexterity of movements is achieved in the human hand in part due to the biomechanics of the hand and in part due to the neuromuscular control. To achieve human-like dexterity we have designed a robotic hand called the Anatomically Correct Testbed (ACT) Hand that possesses many of the biological features of the human hand (see Figure 3). The ACT Hand is developed with the aim to further our understanding of human biomechanical structure and neural control strategies that are important for future robotic and prosthetic hands. The local nonlinear interactions between the muscle excursions and joint movements are mimicked in the ACT Hand by bone shapes that match human bones and by the properties of the tendon hood that connects the actuators to the finger bones (Wilkinson et al., 2003, Deshpande et al., 2008). The anatomical properties allow us to implement biological control strategies such as direct muscle control. We have developed the control software to achieve desired muscle actuation for direct muscle control and also to determine muscle actuation, using an optimization routine, for given end point position and joint stiffness.

Figure 3. ACT Hand showing anatomical bone segments with muscle-motors acting via 'tendons' with realistic insertions and redundancy.

Inverse mapping of EEG

Despite the fact that the ECoG provides higher spatial specificity and signal-to-noise ratio (SNR) than the EEG, its applicability is limited due to its invasive nature. For practical purposes, we would like to get the same amount of information about cortical activity from the non-invasive EEG.

Recent research has shown that sensorimotor high gamma activity can be found in the EEG recorded over sensorimotor areas (Ball et al. 2008). Inverse mapping methods allow the estimation of the cortical activity from the EEG and thus, produce ECoG-like signals. To compute the inverse mapping an electrical model of the head is required that provides a mapping of putative neuronal activity to the scalp. For the most accurate mapping a high number of electrodes and subject-specific models are required. The latter are usually constructed from anatomic magnetic resonance (MR) images. Since EEG electrodes have to be applied frequently and the creation of the individual head models is time consuming and expensive, such an approach would not be very practical. On the other hand, BCIs could be more robust when information about the cortical source of the signal is included. For example, it is very unlikely that EMG artifacts are mapped exclusively to sensorimotor areas and consequently, inverse mapping would allow for a distinction between genuine cortical signals and artifacts. Moreover, the information-transfer rate could be increased by using faster rhythms, such as the high gamma band, to convey information.

In a current study, we examine whether a limited electrode setup and a generic head model can be used to map high gamma activity in sensorimotor areas (Darvas et al., 2010). Ten subjects participated in this study. Subjects were asked to perform voluntary abductions of the right index finger (left index finger for one left-handed subject) in random intervals between four to seven seconds. A total number of 100 movement trials were recorded. We used a 3D localizer to measure the position of the twenty-seven electrodes used in this experiment (see Figure 4(a)). These electrode positions were then subsequently used to construct the head model. To be able to process the EEG signal the EMG of the right or left extensor indicis muscle was recorded. To get a good spectral resolution the signals were sampled at 4800 Hz. We used a tissue segmentation of the Montreal brain phantom into skin, outer skull, inner skull and white/gray matter interface as a generic head model. This model was warped to the measured 10-20 electrode positions to match the subject's geometry (Darvas et al., 2005). The warped head geometry was used to compute an electrical boundary element (BEM) forward model for each subject. A weighted minimum norm algorithm was used to compute the inverse projection matrix. Source orientations were assumed to be fixed and perpendicular to the white/gray matter interface.

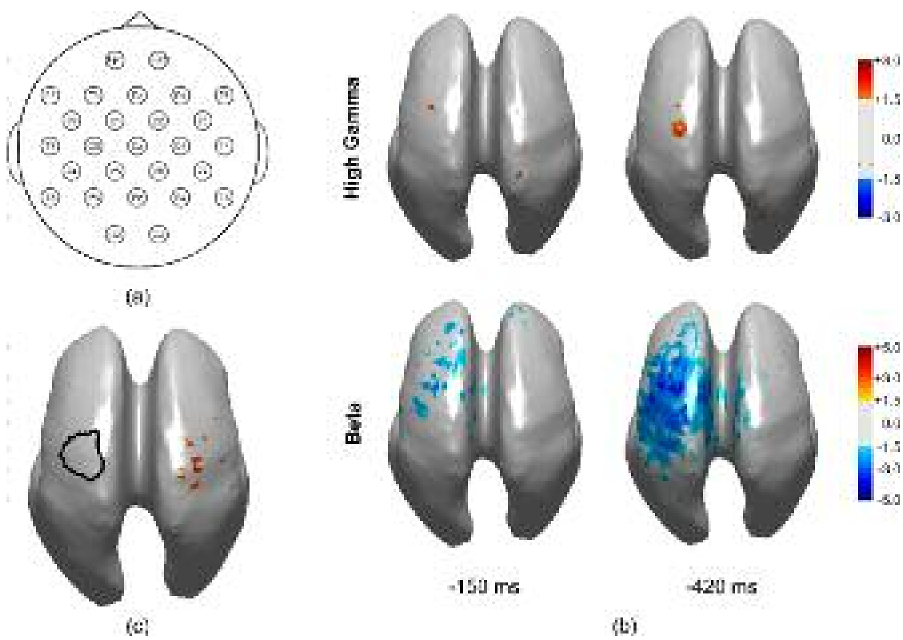

Figure 4. (a) Electrode setup for the inverse mapping experiment (b) Z-scores of beta and high gamma activity (average over nine right-handed subjects) (c) Brain areas which are phase synchronized (red spots) with the region of interest on the left hemisphere (marked in black). Modified from Darvas et al., (2010).

Statistical analysis of the mapped EEG activity showed high gamma activity between 80–100 Hz about 400 ms prior to the movement (EMG) onset. At the same time the well-documented decrease of the power in the beta frequency range was observed. Figure 4(b) shows the averaged Z-score maps for the nine right-handed subjects. We see a spatially focused high gamma activity in premotor (about 400 ms prior to movement) and motor areas (about 150 ms prior to movement). We also computed the phase synchronization between cortical areas, using the phase-locking value (PLV), and found for the first time a interhemispheric phase locking of the high gamma activity starting about 400 ms before movement onset. Figure 4(c) shows the region of interest and the phase locked cortical areas.

With the selected methods we were able to show consistent results in ten subjects, including high gamma power increase over sensorimotor areas and high gamma phase coupling between the hemispheres. The advantage of the inverse mapping that was used is its real-time capability. The head model, which has to be computed once for each subject, takes about 10 minutes on a standard laptop. The inverse mapping is a simple matrix multiplication which can be computed in milliseconds, and thus works for real-time applications. A next step is to research whether single-trial detection is possible and to analyze to which extent this new feature improves robustness of classification and speed of communication.

Discussion and Conclusion

Our results illustrate the range of capabilities of current BCI systems and demonstrate the potential of BCIs to become useful assistive devices. The P300-based control of the humanoid robot and the sensorimotor rhythm control of Google Earth show that different applications may benefit from different control paradigms. Event-related potentials are fast and easy to detect, however, they are also dependent on external stimuli. Event-related oscillations are slower and more difficult to detect, however, self-paced control can be realized without the need for external sources. It may be possible to combine these two control paradigms to reap the benefits of both.

The non-stationary and inherent variability of the non-invasive EEG makes the direct control of neuroprosthetic devices using EEG signals difficult. The results that individual finger movements from both the ipsi- and contralateral hands can be discriminated from oscillatory ECoG activity provided further evidence of the usefulness of this minimally invasive recording technique. These findings have important implications for neurorehabilitation, suggesting, in particular, the possibility of regaining ipsilateral movement control using signals from an intact hemisphere after damage to the other hemisphere. From a machine learning and pattern classification point of view, our results also show that the best performance can be achieved only by the identification of the optimal BCI configuration, which necessitates a more detailed understanding of the function of the human hand and its neuromuscular properties.

The ACT hand, by imitating human biomechanics, contributes to the above-mentioned aim. For the ACT Hand we have analyzed the complex relationship between the muscle actions and joint movement defined by the moment-arm matrix (Deshpande et al., 2008). It is well known that the moment-arms for the hand muscles are configuration dependent and vary substantially with changes in posture. Using the ACT hand, we have been able to determine the moment-arm relationship which is difficult to determine for the human hand. Using the moment-arms relationship, we designed controllers for muscle actuation to track the desired finger end point motions (Deshpande et al., 2009).

The finding that the use of inverse mapping techniques allows the identification of spatially localized high gamma activity may result in new opportunities for EEG-based BCIs. While high gamma power increase has been described in detail in the EEG literature, we reported for the first time phase locking in the high gamma range between motor areas during movement. ECoG electrode grids are usually implanted over one hemisphere only. Therefore, it has not been possible to study interhemispheric synchronization in the ECoG. Our method, being based on EEG, allows the investigation of questions which otherwise would require invasive recording techniques.

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A NEURO VR-BASED VERSION OF THE MULTIPLE ERRANDS TEST FOR THE ASSESSMENT OF EXECUTIVE FUNCTIONS: A POSSIBLE APPROACH

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This paper presents a study aimed at developing a tool for the assessment of executive functions in patients with different etiologies by customizing a virtual reality (VR) version of the Multiple Errands Test (MET) (Shallice & Burgess, 1991; Fortin et al., 2003). The MET is an assessment of executive functions in daily life which consists of tasks that abide by certain rules. It is performed in an actual shopping mall-like setting where there are items to be bought and information to be obtained. The specific goal of this study was to conduct a pilot study using the virtual version of MET (VMET) with both control subjects and patients suffering from Parkinson's disease and from stroke. The task was supported by the employment of an advanced technology able to ensure an ecologically valid context for the patient. Specifically, the MET procedure, previously modified according to the requirements of the NeuroVR software system, was presented via a virtual supermarket. Subjects were requested to select and buy various products presented on shelves with the aid of a joy-pad. The procedures developed and employed during this pilot phase, results obtained for the two clinical samples and the implications for the assessment of executive functions are addressed in this paper.

Keywords: Virtual Reality, Executive Functions, Multiple Errands Test (MET), Daily Life Tasks, NeuroVR

Introduction

This paper presents a study aimed at developing a tool for the assessment of executive functions in patients with different etiologies, in particular Parkinson's disease (PD) and cognitive impairment due to acquired brain injury (including stroke), by customizing a virtual reality (VR) version of the Multiple Errands Test (MET) (Shallice & Burgess, 1991; Fortin et al., 2003). This task is supported by the use of advanced technologies capable of providing an ecologically valid context for the patient while he or she is involved in a complex planning task.

The "dysexecutive syndrome"

The term "executive functions" refers to a set of behavioral competencies which include planning, sequencing, the ability to sustain attention, resistance to interference, utilization of feedback, the ability to coordinate simultaneous activity, cognitive flexibility (i.e. the ability to change set), and, more generally, the ability to deal with novelty (Crawford, 1998). The neural substrates of these competencies are considered to lie in the prefrontal cortex. These abilities play a critical part in complex social behavior, help to suppress improper actions and to focus on purposeful information.

The "dysexecutive syndrome" refers to a cluster of deficits in executive functions. Individuals who suffer from executive function impairments, including attention, planning,

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problem solving and behavioral control (Shallice & Burgess, 1991; Manly et al., 2002; Burgess et al., 2000) present problems of starting and stopping activities, the difficulty in mental and behavioral shifts, increased distractibility and difficulties learning novel tasks despite the fact that their "basic" cognitive abilities are preserved (Shallice & Burgess, 1991). Such individuals thus demonstrate difficulties in Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) functioning (Fortin et al., 2003; Chevignard et al., 2000). Many different categories of subjects can be characterized by this syndrome, showing similar symptoms, with different levels of severity and various forms of resulting behavior, such as patients suffering from different forms of dementia, patients with attention disorders and hyperactivity and subjects suffering from schizophrenia (Castelnuovo et al., 2003). Both the literature and the daily clinical experience of the health care professionals involved in the present study have highlighted the frequency and intensity of difficulties related to frontal lobe deficits in these patients.

Loss of executive functions is primarily a consequence of brain injury located in the prefrontal cortex area. The most common causes of executive functions impairments are neurological conditions including frontal lobe damage due to traumatic brain injury, pervasive CNS damage such as stroke (Baddeley & Wilson, 1988) and those with specific pathologies such as Parkinson's disease (PD).

In recent years, several studies have focused their attention on the distribution of neuropsychological impairments in stroke patients, together with the role of these cognitive profiles in predicting patient functional outcomes. Nys, Zandvoort et al. administered an exhaustive neuropsychological examination to 190 patients, also recording clinical (neurological and neuroradiological) and demographic information (Nys et al., 2007). A disorder in executive functioning, abstract reasoning, verbal memory, and/or language was present in 60-70% of the patients.

With regard to PD patients, in addition to motor symptoms, such as bradykineasia, rigidity and tremor, cognitive deficits have been extensively observed, resembling those following frontal lobe damage (Altgassen et al., 2007). In particular, examination of cognitive function often reveals mild to moderate deficits, including visuospatial impairment, attentional set-shifting difficulties, working memory impairment and poor executive functions (Sammer et al., 2006; Lewis et al., 2003; Uekermann et al., 2004). For instance, patients with PD exhibit planning deficits on the Tower of London task (TOL) (Shallice, 1982), which requires forward planning and subsequent execution of a sequence of moves, particularly in unmedicated states (Cools et al., 2001). Disturbances of the dopaminergic system are thought to play a role in the development of frontal executive impairment (Sammer et al., 2006) and indeed, dopaminergic medication may improve planning through increased prefrontal blood flow Cools et al., 2001).Working memory deficits have often been argued to underlie cognitive deficits in PD (Lewis et al., 2003). According to this hypothesis, Kliegel et al. (2005) reported that PD effects on a task involving planning overlapped with differences in working memory capacity. To summarize, selective cognitive impairment in PD is associated with decrements in working memory that require executive processing, indicating frontal lobe dysfunction.

The Multiple Errands Test (MET)

On a methodological level, the assessment of executive functions under typical clinical or laboratory conditions is unsatisfactory for several reasons (Rand et al., 2009). In such settings, planning, multi-tasking or problem solving are usually done via pen and paper tasks rather than being presented in an actual or simulated manner. Among the most frequently employed tools within the clinical context are the Stroop Test (Stroop, 1935), the WCST (Grant & Berg, 1948), the TOL (Shallice, 1982), the Progressive Matrices Raven, 1948), and Elithorn's Labyrinth, which are all pencil and paper tools and which present trials independent from any activities of daily living, and for this reason lacking in ecological validity.

There are also tools developed to measure executive deficits in situations similar to daily ones, such as the Behavioral Assessment of Dysexecutive Syndrome, the Dysexecutive Questionnaire (BADS & DEX) (Wilson et al., 1996) and the Multiple Errands Test (MET) (Shallice & Burgess, 1991).

The MET is an assessment of executive functions in daily life originally developed by Shallice and Burgess (1991) specifically for high functioning patients and adapted into the simple version (Alderman et al., 2003) and the hospital version (Knight et al., 2002). It consists of three tasks that abide by certain rules and is performed in a mall-like setting or shopping center. The tasks vary in terms of complexity (e.g. buy a small brown loaf vs. discover a currency exchange rate), and there are a number of "hidden" problems in the tasks that have to be appreciated and the possible course of action evaluated (e.g., one item asks that participants write and send a postcard, yet they are given no pen). In this way, the task is, like many situations outside the laboratory, quite "open-ended" or "ill-structured" (Goel & Grafman, 2000; Burgess et al., 2006). There are many possible courses of action, and it is up to the individual to choose one.

After the tasks and the rules have been explained, patients are able to plan and choose the sequence of actions to complete the tasks. In this way, the executive functions stimulated are numerous, from the ability to plan a sequence of actions, to problem solving and to cognitive and behavioral flexibility.

The tester follows the participant, recording mistakes of different kinds. Scoring of the MET relates to the numbers of mistakes of observed behavior in different categories including non-efficiency, rule breaking and use of strategies mistakes in addition to the partial and complete mistakes of completing a task and the total number of mistakes.

Being a "real-life" multitasking test requiring the performance of very common daily actions, the MET has good ecological validity (Burgess et al., 2006).

It also has good psychometric properties. Knight et al. (2002) reported inter-rater reliabilities ranging between .81 to 1.00 for the various measures of the MET, and an internal consistency (Cronbach's alpha) of .77.

Studies have shown that it is moderately correlated with most of the items in the Dysexecutive questionnaire (DEX), which assesses executive functions in everyday life (Alderman et al., 2003). Moreover, Dawson et al. (2005) have shown that Multiple Errands performance (using a hospital-based version) not only correlates well in CVA patients with self-report measures of everyday ability using the Sickness Impact Profile Bergner et al., 1981) and the Mayo-Portland Adaptability Inventory (Malec et al., 2003), but also with objective assessment of daily living skills using the Assessment of Motor and Process Skills [AMPS] battery, e.g., (Fisher, 2003).

The Virtual Multiple Errands Test (VMET)

To perform the Multiple Errands Test, the user has to go with the therapist to a real mall, with walking and mobility abilities required for both reaching the target place and moving into and around the mall. This could present a problem if the patient has motor difficulties. In addition, this procedure could take a long time, for both patient and therapist, which could instead be used for more training in the rehabilitative setting. Finally, real shop features and structure are totally uncontrolled by the therapist, so that unpredictable and potentially disturbing changes may occur when the test takes place.

Virtual reality (VR) has great potential for use in the rehabilitation of everyday life activities, involving cognitive and motor functions. The use of simulated environments, perceived by the user as comparable to real world objects and situations, can overcome the limitations of the traditional Multiple Errands Test, by keeping intact its several advantages.

Over the past twenty years progress in technology has provided clinicians with new opportunities for evaluation and treatment of neuropsychological disorders, which were not available with traditional methods. In particular, with the introduction of VR tools, it has become possible to assess and train patients in ecologically relevant environments (Morganti, 2004; Morganti et al., 2007).

The use of computerized tools, and in particular VR, presents specific advantages: adaptability to varying user abilities, compensation for sensory deprivation and motor impairments, a high level of engagement and motivation, repetitive training which may, in some cases, be used at home, multi-sensorial stimulation and feedback, and more realistic tasks that are safe and suitable for rehabilitation.

The realism and engagement of VR tools may also help to transfer learning to the real world (Rizzo & Kim, 2005). In the following paragraphs, two virtual scenarios developed for the VMET will be presented–the IREX VMall and the NeuroVR supermarket.

A first virtual scenario for the VMET: the IREX VMall

Rand, Rukan, Weiss and Katz (2009) have developed a first version of the Virtual Multiple Errands Test (VMET) as an assessment tool for executive functions [17]. It was implemented within the Virtual Mall (VMall), a new functional video-capture virtual shopping environment (Rand et al., 2005a). The VMall is a functional virtual environment currently consisting of a large supermarket which was programmed via GestureTek's IREX video capture virtual reality system. This system includes a single camera, which films the user and displays his or her image within the virtual environment and interaction is done using active movements (Rand et al., 2005b; Weiss et al., 2004). More specifically, users stand or sit in a demarcated area with a chroma key backdrop viewing a large video screen that displays simulated environments (Rand et al., 2009). A single camera films the user and displays his or her image within the virtual environment. The user's movements are processed on the same plane as screen animation, text, graphics, and sound, which respond in real time. Therefore, the user sees himself or herself in the virtual environment and interacts using his or her own natural movements (Weiss et al., 2004). This system has been used in rehabilitation and has been shown to be suitable for use with patients experiencing motor deficits, cognitive deficits, or both (Kizony et al., 2005; Rand et al., 2007; Reid, 2002; Sveistrup, 2004).

Based on this VR platform, the VMall is a virtual supermarket that encourages planning, multitasking, and problem solving while practicing an everyday shopping task (Rand et al., 2005). It was developed to provide post-stroke participants with the opportunity to engage in a complex, everyday task of shopping in which their weak upper extremity and executive functions deficits can be trained. Within this environment, the products are virtually selected and placed in a shopping cart using upper-extremity movements. The VMall has been shown to provide an interesting and motivating task which can offer post-stroke participants an opportunity to practice different shopping tasks without leaving the treatment room (Rand et al., 2007). Since it is operated within a clinical setting, it is safer, less time-consuming and less expensive compared to shopping in a real mall. In addition, the therapist can control different parameters, such as number of items purchased or their location within the store, in order to adapt the level of the task to the patient's needs. In a previous study, the VMall was found to be sensitive to differences in the shopping time and number of mistakes between post-stroke participants, healthy young participants and healthy older participants on a simple shopping task of four items (the 4-item test) (Rand et al., 2007).This initial research, entailing the use of a simple shopping task, provided support for the development of a virtual realization of the MET.

In particular, in another study an adapted version of the MET – Hospital Version was implemented within the VMall (Rand et al., 2009). It consisted of the same number of tasks (items to be bought and information to be obtained) as the MET and the instructions were identical, but the products were changed to those that could be found in the VMall. The third task (meeting the tester at a certain time) was changed to checking the contents of the shopping cart at a certain time. For this reason a digital clock appeared on the bottom left corner of the screen showing the real time. The participant was given a task sheet and pen (as in the real mall). A small table was placed near the participants for ready access to the sheet and pen while the participant activated the VMall. This VMET was administered while the participants experienced the VMall.

Preliminary results from this study, which included three groups–post-stroke participants, healthy young participants and healthy older participants, showed the ecological validity and initial construct validity of the VMET implemented within the VMall environment as an assessment tool for executive functions. In particular, the VMET was able to differentiate between two age groups of healthy participants and between healthy and post-stroke participants thus demonstrating that it is sensitive to brain injury and aging and supports construct validity between known groups. In addition, significant correlations were found between the MET and the VMET for both the post-stroke participants and older healthy participants. This provides initial support for the ecological validity of the VMET as an assessment tool of executive functions.

In another study, conducted on four post-stroke participants, the intervention focused on improving multitasking while the participant was engaged in a virtual shopping task. Instruments included the Multiple Errands Test in a real mall and in the VMall (Rand et al., 2009). Among the other results, the percentage improvement (decrease in mistakes) on most of the measures within the MET and VMET for all four participants was substantial–the participants made fewer mistakes post-intervention in comparison to pre-intervention. In addition, the participants demonstrated more confidence in the real mall task and broke fewer social rules during post-intervention testing, despite the fact that such rules were not practiced in the VMall. This data supports the VMall's potential as a motivating and effective intervention tool for the rehabilitation of people post-stroke who have multitasking deficits during the performance of daily tasks.

For the study presented in this paper we developed another VR-based Multiple Errands Test. More specifically, as shown in the following paragraph, using the NeuroVR software we have customized a VR version of the Multiple Errands Test (MET) (Shallice & Burgess, 1991; Fortin et al., 2003) in order to develop a tool for the assessment of executive functions in patients with different etiologies, in particular Parkinson's disease and cognitive impairment due to acquired brain injury, including stroke.

A new virtual scenario for the VMET: the NeuroVR supermarket

The analysis of the clinical features of the subjects involved in the present study has led to the use of an interactive technology developed for clinical and rehabilitative purposes, the NeuroVR software.

It is a free VR platform based on open-source software. The software allows non-expert users to adapt the content of 14 pre-designed virtual environments to the specific needs of the clinical or experimental setting (Riva et al., 2009). Using NeuroVR, the user can choose the appropriate stimuli from a database of objects (both 2D and 3D) and videos and easily place them into the virtual environment. The edited scene can be visualized via the Player using either immersive or non-immersive displays. Currently, the NeuroVR library includes 14 different virtual scenes including an apartment, office, square, supermarket, park classroom and other scenes.

The NeuroVR Editor was built using Python scripts that create a custom graphical user interface (GUI) for Blender Riva et al., 2009). The Python-based GUI has the ability to hide all the richness and complexity of the Blender suite, thereby exposing only the controls needed to customize existing scenes and to create the proper files to be viewed in the Player.

Through this platform, in order to develop a specific tool for the assessment of executive functions, a new scenario was created. In particular, the original virtual scene of the supermarket has been customized through different stimuli chosen from a database of objects.

The final application consists of a virtual supermarket, shown in Figure 1, where there are items to be bought and information to be obtained. Subjects are able to select and buy various products presented on shelves with the aid of a joy-pad.

The Multiple Errands Test procedure was modified according to the structure and the features of the system involved in the study.

In particular, subjects were invited to buy some items following a defined shopping list (e.g., a chocolate bar or two

Figure 1. A screenshot of the virtual supermarket.

products from the refrigerated products aisle) and to obtain some information (e.g., the closing time of the supermarket or the number of shelves which sell fruit) following specific rules:

- you must carry out all tasks but may do so in any order;
- you are not allowed to enter any aisle unless you need items there to complete part of your assignment;
- you are not allowed to go into the same aisle more than once;
- you are not allowed to buy more than two items per category of item;
- take as little time as needed to complete this exercise without rushing excessively;
- do not speak to the person observing you unless this is part of the exercise.

While completing the Multiple Errands Test procedure, the time of execution, total errors, partial tasks failures, inefficiencies, rule breaks, strategies and interpretation failures were measured.

The scoring key for these variables are the following:

- for errors in executing the tasks, the scoring range was from 11 (the subject has correctly done the tasks) to 33 (the subject has totally omitted the tasks);
- for inefficiencies, the scoring range was from eight (great inefficiencies) to 32 (no inefficiencies);
- for rule breaks, the scoring range was from eight (great rule breaks) to 32 (no rule breaks);
- for strategies, the scoring range was from 13 (good strategies) to 52 (no strategies);

• for interpretation failures, the scoring range was from three (great interpretation failures) to six (no interpretation failures) and
• for partial task failures, the scoring range was from eight (no errors) to 16 (great errors).

Specific items of partial task failures were the following:

• "searched item in the correct area";
• "maintained task objective to completion";
• "maintained sequence of the task";
• "divided attention between components of task and components of other VMET tasks";
• "organized materials appropriately throughout task";
• "self corrected upon errors made during the task";
• "no evidence of perseveration";
• "sustained attention throughout the sequence of the task (not distracted by other stimuli)."

Method

VR environments

The virtual environments employed in the study present two different scenarios–a food market, for the training in navigation and of object selection and a supermarket, which is larger and more complex, for the evaluation phase. The subject-environment interaction was based on semi-immersion (scenes were visualized on a large screen via video-projector) and objects were selected using a wireless joy-pad.

Population

The study included three samples–a sample of healthy adults with no history of neurological disease and two different clinical samples. For all three samples, subjects were selected with an age between 50 and 70 years old.
The clinical samples consisted of five patients suffering from Parkinson's disease (mean age = 66.6 years, std.dev = 12.4; mean number of school years = 6.2 years, std.dev. = 3.8; MMSE = 25.8, std.dev. = 3.3) and 4 patients with cognitive impairment derived from stroke (mean age = 64.2 years, std. dev. = 9.8; mean number of school years = 15.2 years, std. dev. = 2.6; MMSE = 28.33, std. dev. = 1.7).

Patients were selected according to the severity of the impairment. Exclusion criteria were:

• severely impaired mental status: according to neuropsychological assessment;
• presence of severe difficulties in visual discrimination skills and in language comprehension and presence of spatial neglect;
• severely impaired motor function: according to physiatrist assessment.

In particular, patients were excluded from the study who had a severe cognitive impairment (MMSE < 19), a severe motor impairment which did not allow subjects to perform the procedure (scales employed were the Barthel index, the Stroke scale and the NIHSS [National Institute of Health Stroke Scale]), auditory language comprehension difficulties (score at the Token Test < 26,5), object recognition impairments (score at the Street Completion Test < 2,25), spatial hemi-inattention and neglect as assessed by the Behavioural Inattention Test (score < 129/146), excessive state and trait anxiety (score at the State and Trait Anxiety Index > 40) and excessive depression state (score at the Beck Depression Inventory > 16).

The control group consisted of 14 healthy subjects, eight females and six males (mean age = 64.9 years, std. dev. = 9.1; mean number of school years = 12.3 years, std. dev. 4.03; MMSE = 28.41, std. dev.= 1.25), without motor and cognitive impairments according with motor and cognitive assessment. In particular, exclusion criteria were:

• cognitive deficit evaluated by MMSE (cut off: 24);
• motor impairment which does not allow subjects to perform the virtual procedure;
• sensory deficits.

Every control subject obtained MMSE scores superior to the cut off value (24), however, an initially recruited subject was then excluded due to his difficulties in using the joy-pad that were not overcome during the training phase.

The neuropsychological evaluation

A neuropsychological evaluation was conducted on patients previously selected according to the criteria described in the paragraph above. The aim was to obtain an accurate overview of patients' cognitive functioning in order to be compared with the performance on the experimental test.

The following neuropsychological tests were employed:– Corsi's memory span and supra-span, Digit span, Short Story recall and word recall tests, for memory evaluation; the Tower of London Test (ToL), the Frontal Assessment Battery (FAB) and the Trial Making Test (form A and B), to assess the executive functions and attention abilities and the phonemic and semantic fluencies for object denomination.

Procedure

Participants were included in the study after the neuropsychological evaluation. After a training session, they were asked to complete the Virtual Multiple Errands Test procedure.

Two sessions of about 90 minutes were scheduled for each patient. During the first session they underwent the complete neuropsychological assessment, while during the second session, held the following day, the virtual reality Multiple Errands Test procedure within the virtual supermarket was administered.

A training period was first provided in a smaller version of the virtual supermarket environment in order to familiarize participants with both the navigation and shopping tasks.

With the healthy adults population, the evaluation phase was concluded in a single session of about 30 minutes and consisted of the administration of the MMSE (as the criterion for excluding non-eligible subjects), a training phase in VR and the presentation of the virtual version of the Multiple Errands Test.

The five patients suffering from Parkinson's disease were recruited from the Department of Neurosciences and Neurorehabilitation of Istituto Auxologico Italiano (IRCCS, Piancavallo-Verbania) while the four patients with cognitive impairment derived from stroke were recruited from the Stroke Unit of the San Luca Hospital (Istituto Auxologico Italiano) and were accurately selected according to the above-mentioned inclusion criteria (cf. Paragraph 4.2). This phase took about four months. The main features of the patients suffering from Parkinson's disease and of the patients with cognitive impairment derived from stroke are shown in Table 1.

Statistical Analysis

Descriptive statistics were used to summarize the mean values and standard deviations for the VMET outcomes of patients suffering from Parkinson's disease, patients

Table 1
Clinical population characteristics

	Parkinson 1	Parkinson 2	Parkinson 3
Gender (M, F)	M	F	M
Age (years)	47	71	74
School years	13	5	3
Insufficient NPS tests	Trial Making Test (B-A)	Tower of London Trial Making Test (B-A)	Tower of London FAB

	Parkinson 4	Parkinson 5	Stroke 1
Gender (M, F)	F	M	F
Age	63	78	63
School years	5	5	18
Insufficient NPS tests	FAB Corsi's memory supra-span Trial Making Test (B-A)	Tower of London	/

	Stroke 2	Stroke 3	Stroke 4
Gender (M, F)	M	M	M
Age	76	52	66
School years	18	13	13
Insufficient NPS tests	Phonemic and semantic fluencies Word recall test Corsi's span FAB	Trial Making Test (B-A)	Phonemic fluencies Word recall test Trial Making Test (B-A)

with cognitive impairment derived from stroke and healthy subjects. The Mann-Whitney Test was employed to evaluate the VMET procedure with the two clinical groups and the control group. We also analyzed the correlations between neuropsychological tests and the variables of the virtual test in the two clinical groups. Finally, we carried out analyses in order to compare the two different categories of clinical samples (descriptive statistics and Mann-Whitney Test).

Results

Results from analyses carried out on patients suffering from Parkinson's disease and control subjects

Results from the analyses carried out in order to study planning difficulties in patients suffering from Parkinson's disease are the following:

The *Mann-Whitney Test* was employed to evaluate the VMET procedure with the two groups of participants (patient vs. control).

The *time of execution* for the entire task was higher for control subjects than for patients (Asym. Sig. = 0.12). This could suggest that control subjects tend to engage in a more extensive planning activity.

The mean rank for patients was significantly higher for *errors* in executing the task than for control subjects

Table 2
Correlations between neuropsychological tests and the variables of the virtual test (patients suffering from Parkinson's disease)

	Sustained attention		Maintained sequence		Maintained task		Divided attention	
	r	p	*r*	p	*r*	p	*r*	p
SemanticFluencies	-.99**	.00	-.99**	.00	-.99**	.00	-.95*	.01
ToL	-.93	.02	-.92*	.03	-.92*	.03		
Corsi's supra-span	-.91	.03	-.94*	.02	-.94*	.02	-.91*	.03
PhonemicFluencies	-.92	.03						

	Organized materials		Self corrected		No perseveration		Time	
	r	p	*r*	p	*r*	p	*r*	p
SemanticFluencies	-.97**	.00	-.95*	.01		-		
Corsi's supra-span	-.95**	.00		-	.95**	.04	.95*	.01
ToL			.91*	.03		-		
PhonemicFluencies					.93*	.02		
Word recall test						-		
Token test					.88*	.05	-.91*	.03
FAB						-	-.90*	.04
					.91*	.03		
						-		
					.93*	.02		

	Errors		Inefficiencies		Rule breaks		Strategies	
	r	p	*r*	p	*r*	p	*r*	p
SemanticFluencies	-.95*	.02	.97**	.00			-.91*	.03
ToL	-.89*	.04					-.95*	.01
Corsi's supra-span								
PhonemicFluencies	-.91*	.03						
Word recall test	-.96**	.01	.98**	.00	.98**	.00		
Token test								
FAB								
Corsi's mem.Span								

(Asym. Sig. = 0.005) and the same result was also found for the *partial errors* of the seven tasks.

Moreover, the mean rank for *inefficiencies* and *rule breaks* was higher for control subjects than for patients while strategies were lower than patients (Asym. Sig. = 0.002): this means, on the basis of the scoring key employed, that control subjects make less inefficiencies and rule breaks and use more strategies than patients.

A surprising result is that patients make less *interpretation failures* than control subjects, even if not significantly (Asym. Sig. = 0.38).

With regard to this clinical sample, *correlations* between neuropsychological tests and the items of partial errors (where the higher scores correspond to the higher errors) and the other variables of the virtual test are shown in Table 2.

Results from analyses carried out on patients with cognitive impairment derived from stroke and control subjects

Results from the analyses carried out in order to study planning difficulties in patients with cognitive impairment derived from stroke are the following:

Mann-Whitney Test was employed to evaluate the VR-MET procedure with the two groups of participants, both clinical and control.

The *time of execution* for the entire task was higher for control subjects than for patients (Asym. Sig. = 0.34). This could suggest that control subjects tend to engage in a more extensive planning activity.

Besides, the mean rank for patients was significantly higher for *errors* in executing the task than for control subjects (Asym. Sig. = 0.42) and the same result was found also for some of the *partial errors* of the seven tasks and in particular for the item "organized materials appropriately throughout task" (Asym. Sig. = .094).

While the two groups do not differ with respect to *inefficiencies* and *rule break*, the mean rank for *strategies* was higher for patients than control subjects (Asym. Sig. = 0.49), which, on the basis of the scoring key employed, means that control subjects use more strategies than patients.

Finally, control subjects make less *interpretation* failures than patients even if not significantly (Asym. Sig. = 0.14).

With regard to this clinical sample, *correlations* between neuropsychological tests and the variables of the virtual test are shown in Table 3.

Table 3
Correlations between neuropsychological tests and the variables of the virtual test (patients with cognitive impairment derived from stroke)

	Sustained attention		Divided attention		Organized materials		Self corrected	
	r	p	*r*	p	*r*	p	*r*	p
Word recall test	-.98*	.02						
Short Story recall			.98*	.02	.97*	.03	.97*	.03
StateAnxietyIndex	-.97*	.03						
BeckDepressionI.	-.95*	.05						

	Time		Errors	
	r	p	*r*	p
SemanticFluencies	-.96*	.04		
Corsi's supra-span				
ToL				
PhonemicFluencies				
Word recall test			-.97*	.03
Token test				
FAB				
Digit span			-.99**	.00
StateAnxietyIndex			-.98*	.02
TraitAnxietyIndex			-.98*	.02
BeckDepressionInventory			-.99**	.00

Table 4
Descriptive statistics of patients suffering from Parkinson's disease patients, with cognitive impairment derived from stroke and healthy subjects

			Execution Times (min)	Errors	Inefficiencies
Healthy subjects	Mean		16.08	17.64	23.71
		Std.Dev.	7.07	3.9	5.37
Parkinson	Mean		11.35	26.2	20.8
		Std.Dev.	5.47	4.87	1.79
Stroke	Mean		11.56	19	24.5
		Std.Dev.	4.72	2.83	6.14

			Rule breaks	Strategies	Interpretation failures
Healthy subjects	Mean		28.5	37.36	5.86
		Std.Dev.	2.38	8.61	0.36
Patients	Mean		24.8	50	6
		Std.Dev.	3.35	2.55	0.00
Stroke	Mean		28.5	41.25	5.5
		Std.Dev.	2.08	4.03	0.58

Descriptive statistics showing the mean values and standard deviations for the VMET outcomes of patients suffering from Parkinson's disease, patients with cognitive impairment derived from stroke and healthy subjects are shown in Table 4.

Results from the analyses carried out between the two different clinical samples

Descriptive statistics showing the means and standard deviations for the VMET outcomes and a neuropsychological test of patients suffering from Parkinson's disease and patients with cognitive impairment derived from stroke are shown in Table 5.

Results from the analyses carried out in order to compare the two different categories of clinical samples are the following:

Mann-Whitney Test was employed to evaluate the VMET procedure between the two clinical groups.

Results show that patients suffering from Parkinson's disease have a higher mean of different *partial errors* than the other clinical group and in particular of "maintained task objective to completion" (Asym. Sig. = 0.10), "maintained sequence of the task" (Asym. Sig. = 0.30), "divided attention between components of task and components of other MET tasks" (Asym. Sig. =0.59), "no evidence of perseveration" (Asym. Sig. = 0.01) and "sustained attention throughout the sequence of the task (not distracted by stimuli)"(Asym. Sig. = 0.01).

An interesting result is that this difference between the groups is significant with respect to some of the partial errors but not with total *errors* which could indicate their higher selectivity.

Moreover, patients suffering from Parkinson's disease have a significantly higher mean of partial errors of *specific tasks* than the other clinical group and in particular of the task of going to the beverage aisle and asking about what to buy (Asym. Sig. = .01) and of the tasks of buying toilet-paper (Asym. Sig. = .04), a sponge (Asym. Sig. = .04) and a product that is on sale (Asym. Sig. = .02) .

Patients suffering from Parkinson's disease also have a significantly higher mean of *strategies* than the other group, which, on the basis of the scoring key employed, means that they use less strategies than the other group (Asym. Sig. = 0.02).

Table 5

Descriptive statistics of patients suffering from Parkinson's disease and with cognitive impairment derived from stroke

	Parkinson	Stroke
	Mean ± *SD*	Mean ± *SD*
Sustained Attention	12.60 ± 2.07	8.00 ± .00
Maintained Sequence	12.60 ± 2.07	9 ± 0.00
Divided Attention	13.00 ± 1.73	10.50 ± 1.91
No Perseveration	12.40 ±1.94	8.00 + .00
Maintained Task	12.40 ± 2.07	7.75 ± .50
Part.Err. Beverage Task	14.40 ± 3.58	8.50 ± 1.00
P.Err. Toilet-Paper Task	14.40 ± 3.58	8.50 ± 1.00
P.Err. Sponge Task	15.00 + 2.24	10.50 + 2.51
P.Err. Product on sale Task	16.00 ± 0.00	10.75 ± 0.50
Strategies	50.00 ± 2.55	41.25 ± 4.03
Tower of London Test	17.40 ± 7.40	26.75 ± 3.94

As for neuropsychological tests, an interesting result shows that patients with cognitive impairment derived from stroke have a quite significantly higher mean score in the *Tower of London Test* than Parkinson's disease patients (Asym. Sig. = 0.05).

Discussion

Altogether, the results of the analyses carried out within the present study provide initial support for the feasibility of using the VMET as an assessment tool of executive functions. In particular, the procedure was able to detect the cognitive difficulties that are typical of Parkinson's disease and specifically the deficits in planning, which is the strategy that allows the correct execution of the task, in problem solving and in set-shifting (McNamara et al., 2003). Planning deficits have been found in the early stages of PD, and probably reflect the fronto-striatal circuit degeneration (Monchi et al., 2004). These difficulties have been more evident in Parkinson disease patients than in the other stroke clinical group. Indeed our patients suffering from PD used fewer strategies, showed more perseveration and had more difficulties in set shifting and in sustained attention.

Dimitrov, Grafman et al. (2009) compared PD and focal frontal lesion patients on a task assessing concept formation and shifting (California Card Sorting test, CCST). Frontal lobe patients' CCST performances were significantly worse than those of their matched controls on more CCST components than the PD patients' CCST performances in comparison with those of their matched controls. Variations in individual disease histories, progression rates, and symptoms, typical for PD, were found to influence PD patient performances.

Otherwise, our study showed a more consistent impaired performance at the VMET test in PD patients, with respect to stroke patients. This can be partly explained by our stroke patients' characteristics. In fact, lesion site was not a relevant criterion for the inclusion in this clinical sample, since patients with non-frontal stroke localizations were also recruited. For these reasons, comparison results reflected the planning and set shifting deficits typically associated with PD.

On the other hand, it is well known that stroke affects several cognitive aspects of human functioning. In spite of this evidence, very little attention has been paid to research about cognitive sequelae of stroke and cognitive determinants of short-term and long-term functional outcome.

Even if executive functions are traditionally associated with frontal lobe damage, they are present in most stroke patients, also those showing lesions in wider and different cerebral regions. This can be explained by the distributed basis of these abilities, based on networked cortical areas, involving both cortical (parietal, cingulate, premotor, occipital and temporal areas) and subcortical regions (mainly thalamus and basal ganglia) (Barker Collo & Felgin, 2006).

The involvement of executive functions in stroke patient outcome is supported by several studies, showing deficits in information processing speed, abstraction and mental flexibility in patients diagnosed with vascular cognitive impairment (Nys et al., 2007; Mc. Dowd et al., 2003). Our study proved the presence of impaired strategic behavior and set shifting abilities in these types of patients, when compared with matched healthy subjects.

Until now, these deficits have been demonstrated using a wide variety of tasks, a common one being the Tower of London along with various adaptations and expansions which included novel conditions (McKinlay et al., 2008). However, studies typically report performance on a single task or batteries of individual tasks, each of which is designed to isolate only one of these components. The consequence is that there is little data indicating how PD patients perform in more integrated situations, which combine these component processes in a more ecologically valid context.

In our study, Tower of London was employed, obtaining different performances in the two clinical groups, since patients suffering from PD obtained a lower score, differing from the performances in the other neuropsychological tests. This seems to demonstrate the validity of the procedure in showing the differences between the two groups and thereby showing that it is more complete than the generally employed neuropsychological tests. The trial was made up of different subtasks, aimed at assessing specific components of the ability to plan and execute a complex task in an ecological context.

Among these aspects, only a few were insufficient in both the clinical groups and this could be due to the high selectivity in detecting patients' specific deficits. Therefore, this procedure provides more information than the Tower of London Test and the other traditional neuropsychological tests in a reduced time and in an ecological context.

Considering the correlations analyzed within the present study, it's possible to say that they support the content validity of the adopted procedure as the performances were correlated to the traditional tests aimed at assessing memory, divided attention and executive functions. These results were obtained both for Parkinson's and for stroke patients, therefore supporting the validity of the virtual version of the Multiple Errands Test, developed as an assessment tool of executive functions in patients with different etiologies.

Conclusions

As a whole, these results provide support for the feasibility of using the Virtual Multiple Errands Test (VMET) as an assessment tool of executive functions in patients with Parkinson's disease, dementia and cognitive impairment acquired after stroke. These results suggest that the performances detected with regard to times and accuracy of executions are valid criteria in order to highlight the different cognitive capabilities of examined subjects. Moreover, the complexity of the collected data allowed us to distinguish subjects' performances, not only with regard to the number of errors and times of execution, but also with regard to the number of inefficiencies, rule breaks, adopted strategies and interpretation failures.

However, due to the small sample size, these results should be considered preliminary. Further research using the VMET with larger groups and in additional populations is recommended. In fact, employing larger groups of both healthy adults and patients will provide additional support for the use of the Virtual Multiple Errands Test in assessment and rehabilitation intervention.

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BIOFEEDBACK, VIRTUAL REALITY AND MOBILE PHONES IN THE TREATMENT OF GENERALIZED ANXIETY DISORDER (GAD): A PHASE-2 CONTROLLED CLINICAL TRIAL

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Generalized Anxiety Disorder (GAD) is a psychiatric disease characterized by long-lasting anxiety that is not focused on a specific object or situation. Within the treatment of GAD, physical (relaxation and controlled breathing), behavioral (visualization and controlled exposure) and cognitive control strategies (challenging negative thoughts) represent a key part of the treatment, even if they difficult to learn. To overcome this limitation, the EU-funded INTREPID research project (IST-2002-507464) proposes improvement of exiting treatment for GAD through the use of a biofeedback-enhanced virtual reality (VR) system, used both for relaxation and controlled exposure. Furthermore, this experience is strengthened by the use of a mobile phone that allows patients to perform the virtual experience even in an outpatient setting. This approach was tested in a Phase II randomized controlled trial (NCT00602212), including three groups of four patients each, resulting in a total of 12 patients. The first group consisted of the VR and Mobile group (VRMB) including biofeedback, the second of the VR and Mobile group (VRM) without biofeedback, and the third the waiting list (WL) group.

This study provides initial evidence for better efficacy of treatment for the VRMB group. Subjects belonging to this group reported a higher decrease in some of the anxiety psychometric questionnaires after the treatment than both VRM and WL groups, even if the VRM group, too, reported some significant improvements at the end of therapy. Moreover, qualitative reports concerning outpatient use of mobile phones suggests that it can solve a classical problem of VR therapies–the impossibility of using a VR system in the real life context of the patient.

Keywords: Generalized Anxiety Disorder (GAD), Virtual Reality (VR), Biofeedback, Relaxation, Portable Devices

Introduction

Generalized anxiety disorder (GAD) is a common anxiety disorder that typically has an early age of onset, a chronic course and a high degree of comorbidity with other anxiety and mood disorders (Kessler et al., 1994). According to the DSM-IV-TR (APA, 2000) the essential feature of GAD is at least six months of "excessive anxiety and worry" about a variety of events and situations. Anxiety and worry are often accompanied by additional symptoms like restlessness, being easily fatigued, difficulty concentrating, irritability, muscle tension and disturbed sleep. The lifetime prevalence of GAD in the general population

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is 4-7% (Allgulander et al., 2003), while among individuals seeing their physicians for psychological problems, 25% of them have a diagnosis of pure GAD. Indeed, in primary care facilities, GAD is the most frequent anxiety disorder and the second most frequent of all mental disorders (Wittchen, 2002; Barret et al., 1998). The high prevalence of GAD in the general population and the severe limitations it causes point out the necessity to find new strategies to treat it in a more efficient way.

GAD is usually treated with medications and/or psychotherapy. In particular, the two most promising treatments seem to be cognitive therapy and applied relaxation. As shown by numerous studies, both of these treatments are equally effective, (Siev & Chambless, 2007; Wittchen, 2002) immediately and over long-term periods. Cognitive treatment helps patients recognize and alter patterns of distorted thinking and dysfunctional behavior, while relaxation serves to reduce the increased physical arousal often strictly associated with this disorder. In fact, physical arousal can be voluntarily altered with training in relaxation skills that enables patients to shift physical functions voluntarily toward those that naturally occur in a relaxed state (Barlow et al., 1992). Progressive muscle relaxation and general imagery techniques can be used as therapy progresses since the ability to relax, in any place or situation, is vital to reduce anxiety levels.

Even if relaxation represents a useful approach for the treatment of GAD, it presents an important limitation–it is difficult to learn. Traditionally, relaxation techniques are verbally taught by a therapist or recorded on an audiotape. Recently, a series of CDs playing calming music have been used to help individuals relax, showing positive effects on anxiety reduction by achieving psychological benefits including distraction and sense of control over symptoms. Music interventions also have reported good results to reduce state and trait anxiety, to ease stress, and to increase relaxation (Guzzetta, 1989; Zimmerman et al., 1989). These CDs strengthened the positive effect of calm and sedative music with relaxation techniques to achieve enhanced effects. To increase effectiveness, commercial relaxation DVDs have also integrated visual stimuli. In such a delivery, the visual representation of the scenario supports the process of relaxation creating an isolated context in which the subject can feel comfortable.

Virtual reality (VR) can also be used to facilitate relaxation processes in stressed or anxious subjects (Manzoni et al., 2009; Ferrer-García et al., 2009; Manzoni et al., 2008; Gorini & Riva, 2008; Villani et al., 2007) by visually presenting key relaxing images (Freeman et al., 2004). The advantage of VR compared to CDs or DVDs is its ability to induce a sense of presence in the users, that can be defined as the "feeling of being in a world that exists outside of the self " (Riva et al., 2004; Riva, 2009).

The visual presentation of a virtual calm scenario can facilitate patients' practice and mastery of relaxation, making the experience more vivid and real than the one that most subjects can create using their own imagination and memory. This has the ability to trigger a broad empowerment process within the experience induced by a high sense of presence (Riva & Gaggioli, 2009; Villani & Riva, 2008; Villani et al., 2009). VR can be provided using desktops or laptops connected to a variety of peripheral devices, such as head-mounted displays and joysticks and even through different kinds of mobile devices, such as the new generation of portable audio-visual devices, cellular phones and hand-held personal digital assistants (PDA) equipped with enough raw horse power to deliver a believable 3D experience. Another area of continuing research interest has been the use of various biofeedback techniques for the treatment of anxiety disorders (Reiner, 2008; Rice et al., 1993; Rice et al., 1982). Biofeedback therapies use scientific instruments to measure, amplify and feedback physiological information to the patient being monitored. The information assists the patient in gaining self-regulation of the physiological process being monitored.

Biofeedback consists of the use of biosensors and electronic devices for monitoring human physiological reactions so that individuals can see their body functions and how they react to different anxious or stressful stimuli. The idea is that understanding these habitual patterns will allow the person to take steps to change them in order to reduce symptoms associated with different diseases and disorders. Biofeedback-based treatments show the patients their abnormal physiological response levels helping them to recognize when they are becoming abnormally anxious and, in turn, to help control their anxiety. Biofeedback has demonstrated value for hyperarousal reduction training in GAD (Walley et al., 1994), and represents an effective alternative to medications, particularly for patients who do not respond well, who have a potential for dependency, or who refuse to take, prescription drugs.

Unfortunately, one of the main limitations of traditional biofeedback is that subjects receive very simple audio and video feedback information from a computer that processes their physiological data, such as blood pressure, heart rate, skin temperature, sweat gland activity, and muscle tension, in real time. This method is anti-intuitive for many patients, for two main reasons. First, the graphic display of physiological functions often is of little interest for the patient, who is concerned primarily with symptom relief, not physiology. Second, the interaction of the patient with the feedback environment primarily involves verbal communication with the therapist, who advises the patient on the relaxation techniques. This interaction is important from an educational perspective, but reduces the level of the patient's active and intuitive participation.

To overcome this limitation, the EU-funded INTREPID research project (IST-2002-507464) tried to improve the treatment of GAD through the use of a biofeedback enhanced VR system used both for relaxation and controlled exposure. One of the main advantages of VR in association with biofeedback is the possibility to create complex and fully controlled environments with specific features that can be adapted to the needs of any single subject (Riva, 2007; Freeman et al., 2004).

However, a critical issue related to the use of virtual exposure in the treatment of GAD is the lack of availability of a VR system in the real life context of the patient. Both the cost and the setting of the system limit its use to the health care center, hospital or therapist's office. To solve this issue, we included in the protocol the use of a mobile phone, enabling the patient to visualize a guided experiences in an outpatient setting.

Instruments and Methods

Goals

The main aim of the study was to test the approach proposed by the INTREPID project in a Phase II randomized controlled trial (NCT00602212) with GAD patients.

Subjects

One hundred and five consecutive patients seeking treatment in a public health-care institute in Italy were seen for screening interviews for admission to the study. Criteria for participation in the study included diagnosis of GAD following DSM-IV-TR criteria, age between 18 and 50 years, no psychotherapy treatment received for their GA, in case of taking pharmacotherapy, the type and amount of medication had to remain consistent during the experimental period, no history of neurological diseases, mental retardation, psychosis, alcohol or drug dependence, and no migraine, headache, or vestibular abnormalities. Women who were pregnant or breastfeeding were also excluded.

Of these, 91 either did not fulfil the inclusion criteria or were excluded for other reasons such as time constraints or involvement in other treatments. All patients meeting the inclusion criteria were then randomly assigned to the waiting-list group and to one of the two possible treatment conditions described below.

Thirteen patients were randomly assigned to one of the following groups (see Figure 1–Consort Flow Chart–for details)–the VR and Mobile group (VRMB) including biofeedback;, the VR and Mobile group (VRM) without biofeedback, or the waiting list (WL) group. The randomization scheme was generated using the Web site www.randomization.com. After randomization, a patient in the VRM group refused to participate in the study abandoning the trial for family and work reasons.
Finally, 12 patients, nine females and three males, (see Tables 2-3 for details about epidemiological and clinical variables of the sample) entered the treatment phase. The majority of them (70%) had graduated from upper secondary school, were employed at the time of the study and were married.

The study received ethical approval by the Ethical Committee of the Istituto Auxologico Italiano and was recorded in the Clinicaltrials.gov database with the official trial number "NCT00602212".

Clinical Assessment

A semi-structured interview was used in order to identify relevant DSM-IV-TR diagnostic criteria for GAD in the sample. The following psychometric questionnaires were also administered to each patient at pre-treatment and upon completion of the clinical trial:
• Generalized Anxiety Disorder -7 questions (GAD-7, Spitzer et al., 2006), a seven-item valid and efficient tool for screening for GAD and assessing its severity in clinical practice and research.
• Penn State Worry Questionnaire (PSWQ; Meyer at al., 1990), a 16-item self-report inventory designed to assess trait worry and to capture the generality, excessiveness, and uncontrollability characteristics of pathological worry.
• Beck Anxiety Inventory (BAI; Beck et al., 1993), a 21-item scale which covers cognitive, behavioral and physiological symptoms of anxiety. The BAI is a standardized and well-used assessment measure with good psychometric properties used to assess anxiety.

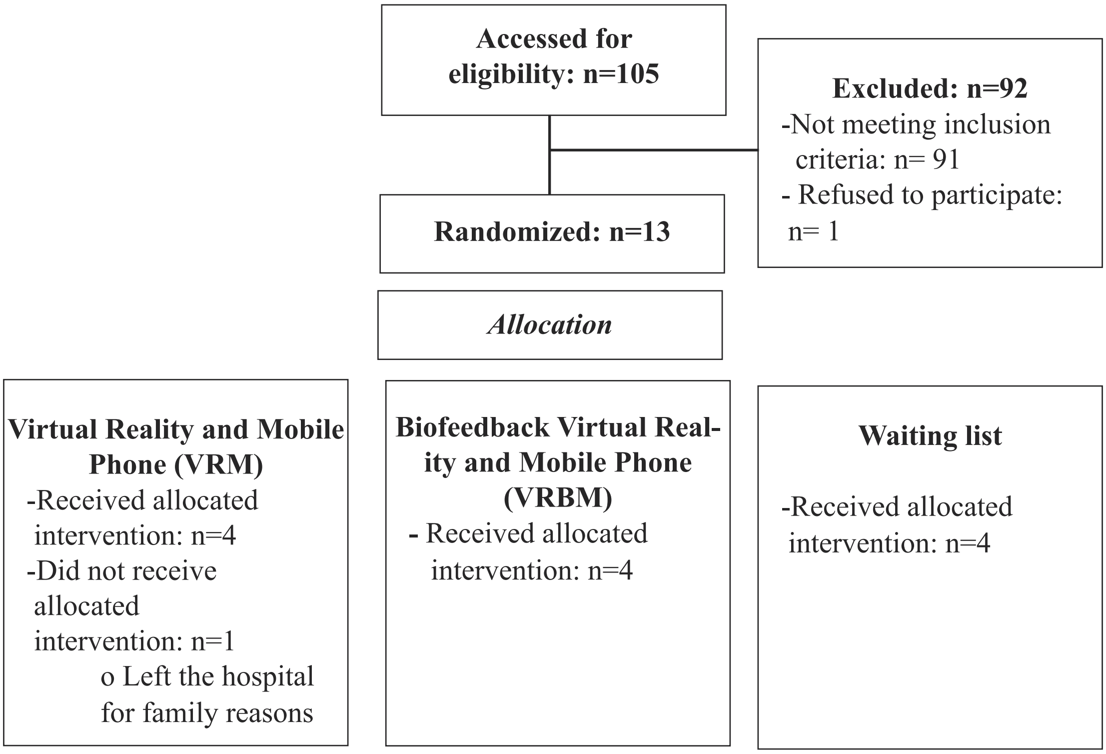

Figure 1. Consort Flowchart for Randomized Trial.

• State-Trait Anxiety Inventory Form Y-2 (STAI-Y, Spielberger et al., 1970), a two-scale questionnaire containing 20 items each that measure anxiety in adults. The STAI clearly differentiates between the temporary condition of "state anxiety" (STAY-Y1) and the more general and longstanding quality of "trait anxiety" (STAY-Y2).
• Hamilton Anxiety Rating Scale (HAM-A; Hamilton, 1959) was one of the first rating scales developed to measure the severity of anxiety symptoms and is still widely used today in both clinical and research settings. The scale consists of 14 items, each defined by a series of symptoms, and measures both psychic anxiety (mental agitation and psychological distress) and somatic anxiety (physical complaints related to anxiety).

The two experimental conditions that received treatment (VRM and VRMB) were also assessed at the beginning and at the end of each of the eight protocol sessions using the following questionnaires:
• State-Trait Anxiety Inventory Form Y-1 (STAI Y-1, Spielberger et al.,1970). The STAY Y-1 addresses state anxiety, which could be defined as a temporary emotional condition characterized by apprehension, tension, and fear about a particular situation or activity.
• Visual Analogue Scale for Anxiety (VAS-A) measures anxiety across a continuum. It is a horizontal line, 100 mm in length, anchored by word descriptors at each end (No anxiety; Very severe anxiety). The patient marks on the line the point that they feel represents their perception of their current state.

At the beginning and end of each training session (baseline and post treatment measures consisting in three minutes of rest condition with eyes opened) the Galvanic Skin Response (GSR) and the Heart Rate (HR) were also recorded. Psychophysiological data was obtained using the GSR/HR Sensor Module, developed by Aurelia Microelettronica Multisensor System during the INTREPID project. The module is a part of the Multisensor System, whose purpose is to obtain analog data from different physiological sensors and, after conditioning and digitalizing, send the data to a host PC using a wireless connection. The GSR/HR sensor module is composed of a GSR block that acquires and digitalizes raw analog skin conductance data, and of a HR block recording heart rate digital samples from a commercial NONIN iPOD Integrated Pulse Oximeter.

Finally, heart rate of the patients included in the VRMB group was also assessed during the treatment sessions, in order to obtain and monitor in vivo measures of their emotional state (biofeedback condition–see below for further details).

Experimental Protocol

To study the efficacy of the different protocols, a between subjects design was used with three experimental conditions and repeated measurements (pre and post-treatment). Specifically, the study compared the following conditions:

1. Virtual Reality + Mobile Phone without Biofeedback Condition (VRM). In this experimental condition patients received an eight-session VR-based treatment (see Table 1) including both relaxation and exposure and techniques supported by HR biofeedback. In sessions one through six, the patient explored a beautiful tropical island (experienced with a head-mounted display and head-tracking) following a predefined path leading to different relaxing areas–Campfire, Beach and Waterfall. In these areas the patients started to relax by observing the flickering campfire, watching waves lapping gently on a shore, or looking at the waterfall and fish pond. Each experience was supported by an audio narrative based on progressive muscle relaxation and/or autogenic techniques. To improve the efficacy of the training and to increase the effects of relaxation, patients experienced at home, using a mobile phone, a non-navigable version of the same virtual reality environment experienced during the therapy. The patient was asked to train relaxation abilities at least once a day for the entire duration of the treatment following the treatment plan provided by the therapist. In sessions seven and eight the patients explored the island again, this time reaching a Gazebo in which they were exposed to pre-selected words or images related to their personal stressful events. The patients were then asked to use the learned relaxation techniques to cope with them.

2. Virtual Reality + Mobile Phone with Biofeedback Condition (VRMB). The patients experienced the same protocol described above, but with the biofeedback support. Specifically, in the sessions with the therapist, HR variations were used to modify specific features of the virtual environment:

Table 1
Clinical Protocol

1. Initial clinical evaluation of the patient's state; 2. The patient is connected with biosensors that record his/her physiological parameters (skin conductance, heart rates, respiration). A baseline measure of these parameters is registered for 3 minutes in rest condition; 3. The patient wears a head-mounted display connected with a pc and handles a joystick; 4. The patient starts exploring the virtual environment: a beautiful tropical island facing on the ocean. The patient, following the narrative recorded by the therapist, reaches the island by boat and explore it. Following a footpath that guides him/her through the island, the patient arrives to the starting point, where different panels indicate the directions to the different target areas. In each of these areas a relaxing exercise is provided; during this training, following the indications given by the voice-guide, the patient tries to relax him/herself. In the VRMB group only, some elements of the virtual environment are directly modified by the patient's heart rate variation recorded in real time. Thus, the patient receives an immediate feedback of his/her level of activation (as in the traditional biofeedback techniques), but with the extra value given by the "presence" experienced in the virtual environment. 5. Once completed the virtual reality session, physiological parameters are recorded again for 3 minutes in rest condition; 6. Final clinical evaluation of the patient's state. 7. Daily relaxation homework using the mobile phone.

a. Campfire (sessions 1-2). The physiological parameter controls the fire intensity–a reduction in the patient's physiological activation reduces fire intensity until it disappears;
b. Beach (sessions 3-4). The physiological parameter controls the movement of the waves: a reduction in the patient's physiological activation reduces the movement of the waves until the ocean becomes completely calm;
c. Waterfall (sessions 5-6): The physiological parameter controls the movement of the water: a reduction in the patient's physiological activation reduces the movement of the water until the water flow becomes completely still;
d. Gazebo (sessions 7-8): The physiological parameter controls the size of a stressful image or video: a reduction in the patient's physiological activation reduces the size of the stimulus until it disappears;
3. Waiting List Condition (WL). This was a control condition, in which patients were included in a waiting list and did not receive any kind of relaxation training.

Hardware (see Figure 2-4):
The hardware elements of the INTREPID system include
• A wireless (Bluetooth) multi-sensor module: GSR/HR Sensor Module including finger sensors that simultaneously measure heart rate and electrodermal activity (GSR).
• The Virtual Reality control unit: Asus G2S portable computer with Intel® Core™2 Extreme Processor X7800, Nvidia GeForce 8600 GT 256 MB DDR3 graphic card, Bluetooth support.
• A head-mounted display: Vuzix iWear VR920 with twin high-resolution 640x480 (920,000 pixels) LCD displays, iWear® 3D compliant.
• The therapist's netbook: (EEPC 100H - BK039X) used to control in real time the features of the virtual environment and to assess physiological parameters.
• A joystick (Xbox Controller)
• A crosscable between the portable computer and the therapist's netbook.
• A smartphone (HTC Touch Pro T7272) for relaxation homework.

Figure 2. (above) GSR/HR Sensore Module:a) the control box; b) the Skin Conductance Response sensors; c) the Blood Volume Pulse sensor.

Figure 3. (above, right) The control unit: a)a personal computer (Asus G2S; Intel® Core™2 Extreme Processor X7800); b)a crosscable; c)a therapist's laptop (EEPC 100H - BK039X); d)A joypad (Xbox Controller); e)a head-mounted display (Vuzix iWear VR920).

Figure 4. (right) The smartphone given to the patients, in which they can experience a Homecare Scenario, achieved by presenting the same virtual environment of the therapist's office training session.

Virtual environment software

The virtual environment developed by Virtools (see Figure 5 and 6).

Figure 5. A screenshot from INTREPID in the VRM Group. The figure illustrates a campfire, one of the relaxing environments shown to the patients during the treatment.

Figure 6. A screenshot from INTREPID in the VRMB Group. During the relaxation exercise a bar in the right of the environment, connected with the patient's physiological parameter their emotional state.

Results

Descriptive methods were used to demonstrate the consistency of the three groups, describing participants' characteristics. Analyses of variance were used to evaluate the baseline characteristics of the three groups involved in the study, and the overall significance of improvement across outcome measures. For each patient, change in psychometric and physiological measures were calculated and analysed using Wilcoxon Signed Ranks Test for matched groups for both intervention and control groups. The magnitude of change was estimated and the 95% confidence intervals given.

In order to obtain qualitative data about the usefulness of the portable device (PDA) subjective reports of participants at the experimental groups were used.

Epidemiological and clinical variables

Table 1 summarizes epidemiological data and clinical characteristics of the three groups of subjects. Non-parametric tests indicated that there were no significant differences in age and years of education of the subjects (Table 2). Similarly, no significant differences were found in their clinical characteristics (PSWQ, BAI, HAM-A, STAI-Y2 and GAD-7) (Table 3).

Table 2
Demographic details by study group

	Group				
	VRMB	**VRM**	**WL**	**F**	**p**
Variables	**Mean (SD)**				
Age	41.25 (13.24)	48.5 (12.662)	51.25 (9.845)	.746	.502
Years of Education	14.25 (2.5)	11.75 (4.787)	10.25 (3.594)	1.164	.355

Table 3
Pre-Treatment and post-Treatment Scores on Psychometric questionnaires of Anxiety for All Groups. As it is possible to see in this table there aren't significant differences in pre-treatment scores on psychometric questionnaires of Anxiety in All Groups

	Group				
	VRMB	**VRM**	**WL**	**F**	**p**
Variables	**Mean (SD)**				
PSWQ Pre	41.25 (13.24)	48.5 (12.662)	51.25 (9.845)	1.332	.311
Post	48.5 (12.396)	47.25 (8.732)	50 (5.292)		
BAI Pre	28.5 (14.059)	26.75 (20.37)	27.50 (13.204)	.012	.988
Post	15.50 (11.733)	18.25 (10.813)	17.75 (6.946)		
HAM-A Pre	25.00 (8.679)	19.50 (3.697)	25.00 (7.439)	.838	.464
Post	15.00 (4.802)	18.75 (9.743)	16.25 (6.702)		
STAI-Y2 Pre	53.25 (2.630)	50.75 (4.573)	58.50 (9.434)	.471	.639
Post	48.50 (12.396)	46.25 (9.912)	58.00 (5.831)		
GAD7 Pre	16.00 (8.367)	10.25 (5.560)	14.25(4.573)	.856	.457
Post	6.50 (4.509)	8.25 (3.948)	8.75 (6.185)		

Psychometric variables

Non-parametric analyses were conducted in order to analyze the treatment effects for pre versus post-treatment on the psychometric variables within the three groups. Results show a significant decrease in the BAI scores (Z=-1.826; p<.05), GAD-7 (Z= -1.826; p<.05) and STAI-Y2 (Z=-1.826; p<.05) in the VRMB group, a significant decrease in the PSWQ scores (Z=-1.826; p<.05) in the VRM group, and a significant decrease in the GAD-7 scores (Z=-1.841; p<.05) in the WL group (Table 4). Non-parametric K-Independent Tests were used to analyze differences between the subjects in the pre and post-treatment anxiety questionnaires. No significant differences were found for p<.05 (BAI: Chi-Square=1.385, p=.548; GAD-7: Chi-Square=4.720, p=.083; HAM-A: Chi-Square=2.192, p=.358; PSWQ: Chi-Square=.299, p=.868; STAI-Y2: Chi-Square=4.606, p=.093), but some differences emerged with p<.1 for GAD-7 (Chi-Square=4.720, p=.083) and STAI-Y2 (Chi-Square=4.606, p=.093).

Table 4
Non-parametric 2-Dependent Samples Test in Anxiety Questionnaires pre and post treatment for all groups

	Group		
Variables	**VRMB**	**VRM**	**BF**
STAI pre-STAI post			
Z	-1.826	-1.473	.000
p	.05	.11	.54
PSWQ pre-PSWQ post			
Z	-1.461	-1.826	-1.604
p	.12	.05	.11
HAM pre-HAM post			
Z	-1.604	-.365	-1.461
p	.05	.42	.11
GAD7 pre-GAD7 post			
Z	-1.826	-.921	-1.841
p	.05	.23	.05
BAI pre-BAI post			
Z	-1.826	-1.461	-1.604
p	.05	.13	.11

Psychometric variables, physiological responses and subjective reports in VRMB and VRM groups

The GSR, the HR, as well as the STAI-Y1 and the VAS-A were recorded at the beginning and at the end of each training session in the VRMB and in the VRM groups. Regarding the physiological responses, we observed that the mean of the differences of HR and GSR before and after each session tended to be higher in the VRMB group than in the VRM group (Table 5). Nevertheless, the difference between the two experimental groups was not statistically significant. Regarding the psychometric variables, we observed that the mean of the differences of STAI-Y1 and VAS-A before and after each session tended to be higher in the VRMB group than in the VRM group (Table 6). Again, the difference between the two experimental groups was not statistically significant.

Table 5
Mean of HR differences between Pre and Post all sessions training

	Group	Mean	Standard Deviation
Mean of HR differences Pre-Post all sessions training	**VRMB**	4,67	3,327
	VRM	2,83	1,169

Table 6
Mean of STAI-Y1 and VAS-A differences between Pre and Post all sessions training

	Group	Mean	Standard Deviation
Mean of STAI-Y1 differences Pre-Post all sessions training	**VRMB**	6,7917	2,71761
	VR	5,2083	3,26886
Mean of VAS-A differences Pre-Post all sessions training	**VRMB**	7,7083	4,28782
	VR	6,4583	3,82563

At the end of the treatment a questionnaire about the usefulness of the PDA was given to all subjects included in the two experimental groups. Ninety-one precent of participants were very satisfied with the PDA, 6% were neutral about it, and 3% were completely unsatisfied. Participants who thought that the PDA was useful said that by using it they could consolidate the training received at the therapist's office, and also that they used it when they were very anxious at home to try to reduce anxiety. On the contrary, the reason for dissatisfaction was explained as the difficulty in using it or in the lack of immersion provided by the PDA compared with the VR environment.

Discussion

Research over the past three decades has shown that the use of virtual reality (VR) was quite effective in treating several psychological problems, especially anxiety disorders. As stated before, VR has been traditionally used to deliver graded exposure, as an adjunct to cognitive-behavioral therapy to treat pathologies such as phobias, post-traumatic stress disorder, and other disorders related to anxious stimuli management. In this study, we used VR in the treatment of GAD, an anxiety disorder characterized by excessive anxiety and worry about a variety of events and situations. Specifically, we tested the following hypotheses:

- The possible use of VR and mobile phones in the treatment of GAD. We used a specific virtual environment–a tropical island–both for controlled exposure and relaxation within an eight-session bi-weekly protocol. Moreover, this experience was strengthened by the introduction of a mobile phone used to visualize guided experiences, similar to the one experienced in VR, in an outpatient setting.

- The possibility of improving this protocol by adding biofeedback to it. Biofeedback therapies use scientific instruments to measure, amplify and feedback physiological information to the patient being monitored. In the present study, the physiological data was used to modify specific features of the virtual environment in real time. For example, the physiological data controlled the movement of the waves: a reduction of the patient's physiological activation reduced the movement of the waves until the ocean becomes completely calm.

The study offered three interesting results. On one side, it confirmed the possibility of using VR in the treatment of GAD. Both experimental groups improved their clinical outcome after the end of the treatment. On the other side, it supports the clinical use of a mobile phone to re-experience and anchor the contents of the VR sessions at home. When interviewed about the usefulness of the PDA, the majority of patients (91%) answered that they were very satisfied with it because it helped them to consolidate the relaxation training in the absence of the therapist. Moreover, the portable device represents a useful instrument that can be used every time the patient needs it, not only at home, but also in every real-life situation in which he/she needs help to become relaxed, solving the problem of the lack of availability of a VR system in the real life context of the patient.

Finally, the study provided initial evidence of the added value offered by the use of biofeedback. Only in the VRMB group did we find a significant reduction in the GAD symptoms (GAD-7) and in the anxiety scores (STAI) from the beginning to the end of the treatment. Regarding the patients' physiological responses, we found a tendency indicating a decrease in HR and GSR between the pre and post-session measurements in the VRMB group, higher than in the VRM.

Even if characterized by some limitations (limited number of subjects, caution in generalizing the results, etc.) a Phase II controlled trial is necessary to understand if a new treatment can helps patients. Our results demonstrate that biofeedback used in combination with VR increases its effect helping patients to better control their physiological parameters and to gauge their success in a more efficient way.

In conclusion, this study represents the first experimental evidence that firstly, VR can also be used in the treatment of GAD, secondly, in a VR treatment, patients can take advantage of a mobile device that delivers guided experiences similar to those experienced in VR in an outpatient setting and lastly, the effectiveness of an immersive virtual relaxing environment that helps patients master the complex training of relaxation can be reinforced by using physiological data to modify specific features of the virtual environment in real time.

Since Phase II of the study has provided promising results, Phase III will be performed in order to consolidate and generalize this initial data.

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RELIABILITY AND VALIDITY OF THE NINTENDO® WII FIT™

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The Nintendo® Wii™ is gaining popularity with clinicians to use with their patients to simulate real world games and sports. Patients enjoy the interaction with the game while the therapist's focus is on improving the patient's function. The Wii Fit™ is being promoted to improve balance. The program begins with assessment tools to give the user an idea of how well they are balancing. This study investigated the reliability and concurrent validity of the Nintendo® Wii Fit™ compared to a known standard in measuring balance, the NeuroCom EquiTest®. The results of this study found that the Wii Fit™ is not reliable or valid in balance assessment as compared to the EquiTest®.

Keywords: Wii, EquiTest, Balance Testing, Center of Gravity, and Left-Right Symmetry

Introduction

A holistic approach to therapeutic intervention for a patient of any age should incorporate balance. This focus is integral in treatment, either to address fall risk in an older adult or to analyze the success of a training program in a young adult. A broad topic, balance has been difficult to measure and document effectively in the past, either to demonstrate improvement with therapy or to provide a means to precisely identify the source of impairment (Dickin & Clark, 2007). However, with current technology, analysis of balance has been quantified with the use of computerized dynamic posturography, an electronic system that employs a force plate equipped with sensors to detect abnormal postural sway during testing (Balance Disorders, n.d.).

Recently, with the development of virtual reality gaming systems, an interactive, three-dimensional experience to train and challenge a patient became available (Holden & Todorov, 2002). Particularly, the use of the Nintendo® Wii™ gaming system is becoming more popular and widespread in therapy for varying populations. There is a multitude of practical advantages associated with its use, including increased patient safety, decreased amount of time, space, and amount of equipment necessary, increased cost efficiency, and quantified results that allow ease of documentation (Bekter, Desai, Nett, Kapadia & Szturm, 2007). In addition, patient experience in rehabilitation programs is improved. Two recent studies reported subjective results from participants that motivation and desire to complete therapy was increased when using the virtual gaming system (Deutsch, Borbely, Filler, Huhn & Guarrera-Bowlby, 2008; Bekter et al., 2007). It is a legitimate supplement to rehabilitation programs because it encourages patients to actively participate in simulated real-life games (Bekter et al., 2007). The activities tend to be more enjoyable to patients than traditional rehabilitation because they are both fun and motivating. Improvements in functional mobility, visual-perceptual processing, and postural control have all been observed following an 11-session training program with the Wii™ (Bekter et al., 2007).

A cost-efficient and commercially available option for the Wii™ that is focused on balance activities is the Wii Fit™. Launched by Nintendo® in 2008 to work with the Wii™ gaming system, the Wii Fit™ utilizes a thin Balance Board™ with a Body Test and Training Games to assess, then improve and track, an individual's static and dynamic balance (What is Wii Fit?, 2009). The Wii Fit™ provides results related to an individual's Body Mass Index, Center Of Gravity (COG), and left-right symmetry via the Body Test. Sensors imbedded within the board are used to directly influence an on-screen character through

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aerobics, yoga, strength training or balance games (Wii Fit™, 2009). Research, however, is lacking on the Wii™, inhibiting a therapist from being able to use all its features with reasonable confidence since its reliability is unknown.

The most commonly used balance assessment tool by physical therapists is the NeuroCom EquiTest®, a research standard tested primarily on older adults to identify fall risk, and used to improve static and dynamic balance (Dickin & Clark, 2007). A visual surround frame with a strain-gauge-integrated force plate, the EquiTest® can be digitally controlled to either translate or rotate in the horizontal plane. These features, combined with the ability to control visual stimuli, are used to examine and challenge each component of balance, consisting of the proprioceptive, visual and somatosensory systems. Reported values provide a way to quantify and document deficiencies in a specific component of balance, as well as to identify if reliance exists on either hip or ankle strategies (Balance Disorders, n.d.).

Overall, research literature offers praise for the EquiTest®, namely reporting positive results regarding sensitivity, test-retest reliability and validity (Monsell, Furman, Herdman, Konrad & Shepard, 1997). One study demonstrated the EquiTest®'s ability to distinguish elderly patients experiencing decline in health as displayed by lower results in five out of six conditions on the Sensory Organization Test (SOT) (Monsell et al., 1997). Another study showed similar results, with the elderly patients experiencing a decline in health showing an increase in response time and sway in all six conditions on the SOT as compared to controls (Wolfson et al., 1992). Regarding test-retest reliability, one study reported an overall interclass-correlation coefficient of 0.66 for the SOT, a score equivalent to fair-good reliability (Camicioli, Panzer & Kaye, 1997). On its own, condition 1 of the SOT has moderate reliability (ICC=.57) (Camicioli et al. 1997). The EquiTest® has also demonstrated predictive validity for loss of balance, with one study reporting moderate-high reliability for all six conditions, as long as they were experienced at least twice on the same day (Ford-Smith, Wyman, Elswick, Fernandez & Newton, 1995). However, despite the wealth of evidence crediting EquiTest's® accuracy and precision, it remains elusive to many average therapy clinics, given its high expense and large space requirement.

The Wii Fit™ is considerably more affordable than the EquiTest®, or other force plates. Nintendo's® suggested retail price for the Wii Fit™ software and Balance Board™ is US$89.99 (What is Wii Fit?, 2009). The Wii™ console and controller must also be purchased in order to use the software. The system's MSRP is listed as $249.99 in the U.S. (Official Wii Launch Details, 2009). Force plates themselves cost thousands of dollars, and the EquiTest® can be purchased for approximately $100,000 in the U.S. (Chaudry, Bukiet, Zhiming & Findley, 2008).

This study aims to investigate the possibility of placing a feasible, more affordable and portable tool for balance into the hands of the average rehabilitation clinic. Using an industry standard, we examined the reliability of the Wii Fit™ and concurrent validity with the NeuroCom EquiTest® to assess for its efficiency and efficacy. The study was approved by the Institutional Review Board at The Sage Colleges in Troy, New York.

Methods

Subjects were recruited using convenience sampling by sending an "e-mail blast" to the Sage Colleges' Troy campus, as well as using posters and word-of-mouth. For homogeneity purposes, participants were included in the study if they were between the ages of 18 and 25 years old and did not weigh over 300 pounds, so as not to exceed the weight capacity of the Wii Fit Balance Board™. Before participating, all subjects completed a university-approved informed consent form and had height and weight measurements taken without wearing footwear. Both values were entered into the machines to help compute their body mass index and balance measurements. In addition to providing their name and date of birth, subjects were screened using a health questionnaire to rule out the possibility of any physical or neurological impairments that may have prevented them from completing both exams successfully. Measurements for height and weight were obtained using a standard tape measure and bathroom scale.

The Nintendo® Wii Fit Balance Board™ with the Nintendo® Wii Fit™ gaming system was utilized for the first half of balance assessments in this study (What Is Wii Fit?, 2009). The Wii Fit™ gaming system includes the Balance Board™, shown in Figure 1, with sensors built in to report distribution of weight between both lower extremities. The latter portion of balance assessments were completed using the NeuroCom EquiTest®, a dynamic force plate using strain-gauge technology and imbedded sensors to sense distribution and shifting of weight.

Figure 1. The Wii Fit Balance Board™ weighs 10 pounds, with the dimensions of 20.5 x 3.2 x 13.4 inches.

Figure 2. Subject performing a trial of the Wii Fit™ Body Test.

The participants were positioned in front of a screen, as shown in Figure 2, to prevent any horizontal or vertical visual cues from influencing their balance or posture (Figueiro et al., 2008). The screen also prevented the subjects from viewing the TV or the investigators so that they were not prompted on how to stand. In addition, the TV volume was turned off, not allowing for any auditory feedback to either provide knowledge of results or to give a point of reference for the subject. Each subject was then asked to stand on the Wii Fit Balance Board™ and complete the "Body Test" on the Wii Fit™ game, which consisted of entering their height and birth date and standing on the Wii Fit Balance Board™ for 20 seconds to complete a "Center of Balance" exam. This test asks the user to stand on the balance Wii Fit Balance Board™ in a normal posture, placing their feet within the two boxes where comfortable. The user is then required to stand as still as possible for 10 seconds while the board measures COG and left-right symmetry. The measures are reported on the screen for COG and the percentages for each foot's amount of weight-bearing. Two trials were completed and recorded on a Data Recording Sheet which mimicked the four square cell that was viewed on the TV screen (see Appendix).

Afterwards, each subject completed two tests on the NeuroCom EquiTest®. For the first set of measurements, the primary investigator lined up the feet of the subjects on the force plate according to the protocol outlined by NeuroCom®, and were asked not to move their feet. First, each completed the first trial of the Weight Bearing Squat test, which required them to stand on the EquiTest® force plate with their feet positioned by the researcher and keep their legs extended for one second (see Figure 3). This test is used to measure left-right symmetry, reported as a percentage for each leg, and was meant to mimic the portion of the Center of Balance test on the Wii Fit™ measuring left-right symmetry. Afterwards, they completed Condition 1 of the SOT, which required the participant to stand on the force plate for 30 seconds while center of balance was measured. This test intended to mimic the Center of Balance test on the Wii Fit™ measuring COG. Both sets of trials were completed twice and documented on the Data Recording Sheet (see Appendix, following page).

Figure 3. Subject performing a trial of the Weight Bearing Squat on the EquiTest® with her feet aligned according to the NeuroCom® protocol.

A second set of measurements was taken, this time with the intention of accounting for any differences in testing protocol between the Wii Fit™, which does not require feet to be lined up, and the EquiTest®. For this set of testing, the EquiTest® force plate was taped to outline the dimensions of the Wii Fit Balance Board™ as shown in Figure 4, and each participant was asked to step onto the plate in a posture and foot position that was most similar to their typical stance (see Figure 5). Values were taken again for both tests, repeated twice, and recorded on the Data Recording Sheet.

After the data was collected, each subject was offered a chance by the researchers to review their results of all trials. The results of each individual's trials on the Wii Fit™ and EquiTest® were reviewed with the subjects upon their completion. The purpose of sharing the results was to inform the participants of any balance abnormalities that were indicated in the findings. Along with this information, brief, qualitative advice was given for how to improve the balance deficits noted. This guidance could be beneficial if utilized, as the participants could potentially enhance their COG and left-right symmetry, leading to improvements in functional performance and prevention of injuries.

DATA ANALYSIS

All values were analyzed using SPSS 15.0. Analysis for reliability of the Wii Fit™ was calculated first using an intraclass correlation coefficient (3,1). Values for COG and symmetry (left-right and forward-behind) were then analyzed using Pearson's Correlation Coefficient and Spearman's Rho, to look at interval and nominal data, re-

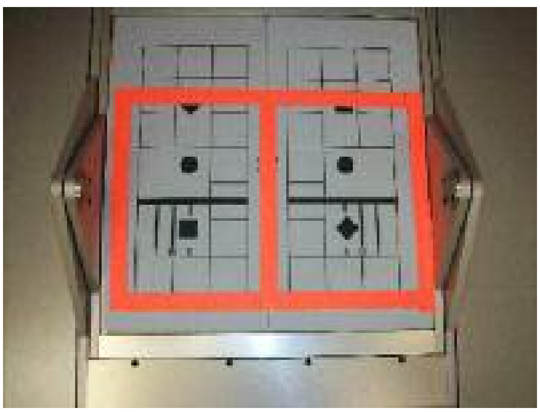

Figure 4. EquiTest® force plate with the dimensions of the Wii Fit Balance Board™ indicated by a tape outline.

APPENDIX

Data Recording Sheet
Name:_______________
Birth date:__/__/____
Height:___'____"
Weight:___lbs.

Wii Fit

Trial One	*Trial Two*
COG:	COG:
Left-Right Symmetry L:___ R:___ Weight:___lbs. BMI:____	Left-Right Symmetry L:___ R:___ Weight:___lbs. BMI:____ BMI= body mass index

EquiTest (without foot alignment)

SOT Trial One:	*SOT Trial Two:*
Weight Bearing Squat Trial One: L:___ R:___	Weight Bearing Squat Trial One: L:___ R:___

EquiTest (with foot alignment)

SOT Trial One:	SOT Trial Two:
Weight Bearing Squat Trial One: L:___ R:___	Weight Bearing Squat Trial One: L:___ R:___

spectively. With regards to the EquiTest®, values were first run to analyze the data from when subjects' feet were lined up according to the NeuroCom® protocol, then when the subjects were allowed to stand comfortably.

Values used for data analysis were first computed from the Data Recording Sheet to account for the variability in the interval and nominal data. Data regarding each subject's left-right and forward-behind symmetry, being nominal data, were reported as either "1" or "2" to indicate which side of either the midsaggital or midtransveral line the subject's COG fell. Left-right symmetry was determined by indicating which side the COG was on using the midsagittal line for reference–a "1" indicated COG to the left, and a "2" for the right. Forward-behind symmetry was also measured and reported by indicating if the COG lay above or below the transverse line drawn in the middle of the box, recorded as a "1" or "2" respectively. The amount of correlation between the Wii Fit™ and EquiTest® for both left-right and forward-backward symmetry was analyzed using Spearman's Rho.

Values for COG were depicted with a dot drawn by the examiner on the four square cell on the Data Recording Sheet simulating the footplate of both the Wii Fit™ and EquiTest®. COG was measured by a standard ruler from the midpoint of the four squares to the COG dot drawn by the examiner. These values, being interval data, were averaged to provide a comprehensive picture. The amount of correlation between COG measurements from the Wii Fit™ and EquiTest® were analyzed using Pearson's Correlation Coefficient.

Results

Thirty-one subjects between the ages of 18 and 25 years old participated in the study (mean = 22.6 ± 1.87). Twenty-three were female and eight were male. The Wii Fit's™ COG measurement was found not to be reliable (ICC = .253). The percentages given for left-right symmetry were also not reliable (ICC = .270). However, using the Wii Fit™ as a measure for body weight was determined to be correlated with the measurements given by a standard bathroom scale (r = 1.000).

When the subjects' feet were appropriately lined up on the EquiTest®, the measurement given by the Wii Fit™ for COG as distance from the origin was not correlated (r = .080; p = .120). The Wii Fit's™ forward-behind data for COG was also not correlated with that of the EquiTest® (r = .218; p = .334). However, a fair level of correlation was detected between the left-right symmetry reading provided by the Wii Fit™ and that from the EquiTest® (r = .532; p= .001). By not aligning the subjects' feet on the EquiTest®, so as to mimic the standing posture on the Wii Fit™, higher correlations were not produced for COG measurements as distance from the origin (r = .147; p = .300), and forward-behind data (r = .147; p = .171). The Wii Fit's™ left-right symmetry percentages were not correlated (r = .210; p = .226).

Figure 5. Subject performing a trial of the Weight Bearing Squat on the EquiTest® without her feet aligned. She is standing in a natural stance to simulate the stance that is used on the Wii Fit Balance Board™.

Dicussion

The purpose of this study was to determine the feasibility of using the Wii Fit™ as a means of quantifying patients' balance affordably in the clinic and at home. Though the Wii Fit™ is a more convenient and cost-effective tool for measuring COG and left-right symmetry than the EquiTest®, it is not as accurate or consistent. The only measurement that was comparable to that of the EquiTest® was left-right symmetry. Even so, the correlation was only fair, and the measurements were not found to be reliable from trial to trial. The COG measurements given by the Wii Fit™ were not correlated with those from the EquiTest®. There was also no consistency in the COG measurements given by the Wii Fit™. The body weight measurement that the Wii Fit™ provided was correlated with the digital reading given by a bathroom scale.

What may account for the difference in the Wii Fit™ compared to the EquiTest® is that they are designed differently for detecting balance. These mechanical variations may contribute to their differing capacities for measuring COG and left-right symmetry. The Wii Fit Balance Board™ is comprised of four sensors that are attached as legs. These sensors are strain gauges, which measure vertical forces applied to them. The positioning of the sensors at the four corners of the Wii Fit Balance Board™ allows for both precise body weight measurement and the recognition of balance shifts in every direction (Iwata, 2009). In the EquiTest®, a dual force plate is located in the base platform, where the subjects stand with one foot on each force plate. The force plates quantify the vertical and horizontal forces exerted on them by each foot via strain gauges, which measure the anterior posterior center of vertical force position (Hirsch, Toole, Maitland & Rider, 2003; Barin, 1992).

When using the EquiTest®, users are prompted to line up their feet with specific markings on the force plate so that their foot placement is symmetrical, with the medial malleoli in line with the force plate's center of rotation to allow the platform and the screen enclosure to rotate around the joint axis of the ankles (Hirsch et al., 2003). Since this may not be a person's natural stance, this positioning may be awkward and it may not reflect the balance measurements that they might have if they were standing as they normally would. The Wii Fit™ does not require users to position their feet in a particular manner on the Wii Fit Balance Board™. Rather, those using the balance board to obtain balance measurements are able to stand comfortably in their natural stance. In this study, upon obtaining data that was not correlated between the EquiTest® and the Wii Fit™ when participants had their feet properly aligned on the EquiTest®, participants were asked to perform additional trials without their feet adjusted to the specifications in order to see if the data would show greater correlation for left-right symmetry and COG measurements. However, regardless of foot positioning on the force plate, correlation of the balance measurements did not improve.

The only measurement that was found to be correlated between the Wii Fit™ and the EquiTest® was left-right symmetry. This correlation only occurred with the trials in which the participants' feet were aligned on the force plate of the EquiTest® as directed. Though the researchers believed that having participants stand without their feet aligned on the EquiTest®, as they would with the Wii Fit™, would improve the correlation of the left-right symmetry and COG measurements, the correlation levels actually dropped. The lack of reliability in the balance measurements given by the Wii Fit™ may be attributed to participants shifting their stance and foot positioning between trials.

A strength of this study is that the balance-measuring capabilities of the Wii Fit™ were compared to the industry's gold standard, the EquiTest®. The narrow inclusion criteria for the age of the subjects adds to the study's internal validity, but at the same time the data from the 18 to 25 year-old age group cannot be generalized to other populations. Another limitation to the study is that the two systems were not designed to examine the exact same balance measures. Rather, the EquiTest® was manipulated to simulate the tests that the Wii Fit™ was performing. The EquiTest® is known for its adequacy in dynamic balance measures, however, only static measures which would be comparable to those accessible with the Wii Fit™ were used.

Conclusion

This study found that the Nintendo® Wii Fit™ may not be used with the same level of confidence to accurately analyze balance as the NeuroCom EquiTest® in the clinic.

As more clinics acquire the Wii Fit™ for use in rehabilitating their patients, physical therapists may feel inclined to use the Balance Test as a quick and easy way for tracking gains in balance throughout the course of treatment. Though an improvement in the COG and left-right symmetry scores can be motivating to patients, these scores do not meet a standard of accuracy for use in documentation.

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TRAPPED IN THE WEB: THE PSYCHOPATHOLOGY OF CYBERSPACE

Tonino Cantelmi[1] and Massimo Talli[1]

In this review the authors, after an initial description of the "Internet phenomenon," particularly of the psychological and psychopathological risks related to its use, propose to the reader a series of works on this theme developed during recent years. In this review many interesting aspects are discussed such as the problem of defining the syndrome and the possible diagnostic criteria, the explanatory models proposed by various authors and possible therapy options to treat the syndrome.

Keywords: Internet, Psychopathological Risks, Explanatory Models, Diagnostic Criteria, Addiction

Introduction

It was around 12 years ago when we studied so-called "internet addiction" for the first time (Cantelmi & Talli, 1998). Our interest in this unique pathology began when a woman from Northern Italy came to our department showing clear dissociative signs after a prolonged exposure to the Internet. We could not identify the precise role played by the Internet. Even though we analyzed her clinical state in detail, we could not understand if it was just an accidental coincidence or a cause of the same symptomatology.

In 1998 the pioneering studies performed by Young in Pittsburgh and other researchers (Young, 1996; Suler, 1996; Brenner, 1997, Griffith, 1997) represented all we knew about this problem until that time. In Italy, very few people could benefit from Net connection and it was not very common to talk about "strange" psychological influences. Since then, the "Queen of the Nets" has spread to a global level by becoming the best means of communication, among all the others. Its spread increased scientific knowledge related to the Net and psychopathologic aspects, and it also made it possible to have access to many kinds of information.

The technology on which the Net is based has changed. The broadband has enabled safer and faster connections, while at the same time the arrival of the telephony and digital TV has made the Internet more useful and attractive. Nevertheless, its anarchic spirit remained pleasantly integral, just like its capability to stimulate fresh mental pathways.

This review intends to examine the most important scientific contributions obtained by authors who contributed in such ways as providing definitions, diagnostic criteria, impact of disorder, theoretical patterns, motivation, net services and toxicity, means of assessment and treatment. As conventionally agreed, we will use the expression Internet Addiction (IA) in order to indicate a series of online disorders and behaviors, united by the same technology, the Internet, and from the same type of use–abuse. Moreover, we will fully discuss the new scientific contributions that our studies developed in the last few years. The contributions represent a new knowledge that we hope will enrich the previous, existing knowledge on the subject.

Definitions

The first computer addiction cases appeared during the 70's and 80's (Shotton, 1991). These kinds of problems were related to PC use-abuse and not to the Internet, since it did not exist yet.

Ivan Golberg, an American psychiatrist, was the first scholar to recognize this "illness" by defining it as Internet Addiction Disorder (1995). He helped to clarify all rela-

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tive diagnostic criteria relating to the Web. Since then, in order to describe this syndrome, several definitions were created in the scientific field such as Internet Addiction (Young, 1996), Internet Dependency, (Scherer, 1997), Compulsive Internet Use (Greenfield, 1999), Compulsive Computer Use (Potenza & Hollander, 2002). IA can be categorized into more specific addictions, such as Cybersexual Addiction, Cyber Relationship Addiction, MUD (multi user dungeon) Addiction, Compulsive Online Gambling, Compulsive Online Shopping, Information Overload Addiction, EBay Addiction and Trading Online Addiction (Young, 1996). Lavenia and Marcucci (2005) provide a further distinction between Cybersex Addiction and Cyberporn Addiction, by assigning the first type of addiction to a sexual interactivity (man-machine-man system) that is completely absent in the second type of addiction (man- machine system).

In his cognitive-behavioral pattern, Davis (1999) suggests the use of the term Specific Pathological Internet Use (as opposed to Generalized Pathological Internet Use) in order to identify any specific form of online addiction.

Carretti offers an explanation on Video Display Dissociative Trance–as outlined by the Diagnostic and Statistical Manual of Mental Disorder (DSM), he confirms that it is a disorder induced by technology. It shows a clinical state that can be related to intense Internet intoxication (Caretti, 2000; Caretti & La Barbera, 2001).

Diagnostic Criteria

Historically, IA has been diagnosed by using unique assessment criteria. In 1996 Young was the first researcher who studied the disorder by proposing diagnostic criteria for Internet Addiction Disorder (Young, 1996). According to Young, it was possible to identify formal aspects of the addiction, such as tolerance, abstinence and craving, in all affected people. Afterwards, she thought to apply the same criteria to pathologic gambling (see table 1). This disorder is considered to be very close to IA phenomenology, since it does not include the consumption of chemical substances (Young, 1998; Potenza, 2006). Some criteria for pathologic gambling, such as “run-up” to the losses, committing illegal acts to finance the game and finding money to relieve a financial situation caused by gambling, were not considered applicable to IA. Indeed, a new specific set of criteria was created and included behavior such as spending more time online than predicted (Johansson & Gotestam, 2004; Leung, 2004).

Shapira and his colleagues (2000) proposed some interesting guidelines that highlight the emotional aspects con-

Table 1
Diagnostic Criteria for Internet Addiction (Young, 1998).

It is necessary that five or more of the following symptoms appear:
1. Do you feel excessively absorbed by the Internet? (Do you think about the previous connection or are you already planning the next online session)?
2. Do you feel the need to spend more time connected to the Net in order to obtain the same level of satisfaction?
3. Have you tried repeatedly to control, to reduce or to interrupt Internet use with no success?
4. Do you feel nervous, depressed or irritated when you try to interrupt Internet use?
5. Do you stay online longer than you planned to?
6. Do you risk negatively affecting important relationships at work or at school because of the Internet?
7. Have you ever lied to your family, therapist or other people to hide the level of your Net involvement?
8. Do you use the Internet to escape from problems or to relieve your dysphoric mood? (Feelings of powerlessness, guiltt, anxiety or depression?)

nected to the resulting loss of control. They also focused their attention on the intense anxieties and worries relevant to immoderate Net use (see table 2).

Until now, IA did not belong to any formal diagnostic system. People affected by the syndrome can be included in the category of disorder of impulses control not differently specified. Nonetheless, proposals to include this type of addiction into the next edition of the DSM became even more persistent. One proposal came from the pages of the authoritative American Journal of Psychiatry, in which J. Block published an article where he identifies IA as a particular type of disorder referable to the compulsive-impulsive specter (Block, 2008).

Table 2
Diagnostic criteria for the Problematic Internet Use (Shapira, 2000)

A. Maladaptive concern related to the Internet, as shown by the following:
1. Concern related to the Internet being viewed as irresistible.
2. Immoderate use of Internet for a period of time longer than planned.
B. Use of the Internet and relative concerns cause clinically significant anguish or weakening of social and professional areas, etc.
C. Immoderate use of the Internet does not happen only for periods of hypomania or mania, moreover, it is not better explained by other disorders.

The Effect of the Disorder

IA effects on people vary in a substantial way. It depends on the methodology of the survey (surveys conducted on the Internet or not on the Internet) and the type of instruments used (questionnaires based on several diagnostic criteria). Generally, online surveys indicate a rate of diffusion between 3% and 11% (Kershaw, 2005; De Angelis, 2006). For instance, Greenfield's survey conducted on a sample of 17,251 subjects with an age between eight and 85 years old, shows a disorder effect rate equal to 5.7% (Greenfield, 1999).

More recently, a survey completed by Korean researchers underlined a lower effect rate (Wang et al., 2003) in which only 3.47% of participants became addicted to the Internet. Most likely, these surveys prove that multiple factors influence differences in obtained results. For instance, while Greenfield (1999) focused his attention only on American users, Wang and his staff members studied only Korean subjects. Moreover, Wang and his collaborators used the Internet Addiction Test proposed by Young. It is an instrument represented by a scale with 20 items called the Likert scale. The structure of this test is very different from the yes/no answers test used for Greenfield's survey. Generally, studies completed on the Net can be more successful at gathering a large quantity of data in a relatively short period of time (Egger & Rauterberg, 1996; Eppright et al., 1999). Studies conducted online can select subjects that use the Internet frequently or that think they may have a problem with Internet use.

Those surveys that are not conducted on the Net on the basis of random selection of subjects represent an important way to carry out studies on IA. Until now, only one survey has been published on this phenomenon among the general population that used offline random sampling. This survey shows a very low diffusion rate varying from 0.3% to 0.7% (Aboujaoude et al., 2006).

Theoretical Patterns

In this review, we will analyze some of the patterns that may help to explain the IA phenomenon.
Young's ACE pattern (1998) summarizes the main factors that can contribute to disorders related to the Internet:
- Accessibility: the easy and immediate accessibility to any online service allows an immediate gratification of the smallest need.
- Control: the very high level of control that can be per-

formed on online activities induces an unreal perception of omnipotence.
- Excitement: the large quantity of stimuli present on the Net allows users to reach a high level of psychological excitement.

In his study, Davis (1999) used a cognitive-behavioral approach, explaining that base for Pathological Internet Use (PIU) comes from problematic cognitions linked to some behaviors that intensify or detain the disadaptive response (see figure 1). This theory highlights cognitions and thoughts of the individual that contribute as the main source of abnormal behavior. According to the author, the disadaptive cognitions related to a person start with the Internet and could refer to himself/herself (by doubting about his/her personal esteem) or to the world (generalizations or thoughts about everything and nothing). The product of these cognitions is a PIU that can be specific or generalized. The specific PIU defines people depending on an Internet-specific function, such as erotic material, gambling, auctions, etc. These types of dependencies are content-specific addictions and will exist regardless of the presence of the Internet. The generalized PIU, instead, includes a generalized and multidimensional overuse of the Internet.

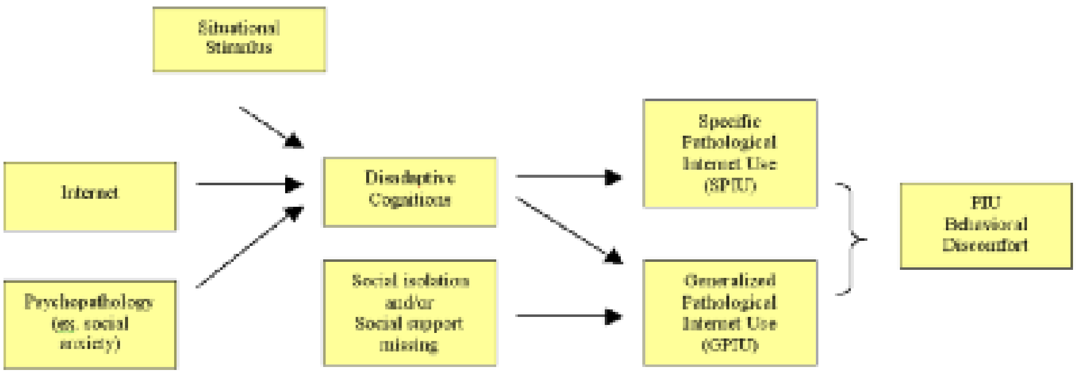

Figure 1. Davis's cognitive-behavioral model (Davis, 1999).

Recently, Cantelmi and Talli (2007) have developed another pattern type (see figure 2). The idea behind this pattern is that during "normal" use of the Net, there should be a progressive increase in experiences, in the same way as the use of major online instruments and services. If the first approach to the Net is usually represented by the use of e-mail or moving quickly from one site to another, then other, more complicated and sophisticated applications will be used, such as chat, newsgroups, MUDs, etc.

In the "pathologic" use of the Net, this process repeats itself, but in a symmetrical way. Regardless of the experiential background acquired with previous connections, the user will gradually downsize the use of the Net by increasing his/her time online progressively. Obsessiveness is typical of specific themes of the Net such as cybersex, MUDs, etc.. The authors distinguishes four precise evolutionary phases that push the user towards become progressively addicted to the Net:

-Entry into the Net: The user initiates contact with the Net through surfing the Internet or exchanging e-mails. The user is bewildered and curious about new experiences. From a relational point of view, he establishes a relationship with the Internet–a new type of relationship defined as "man-machine." Even though the user communicates with other people, these people will become a secondary interest compared to the technological enchantment of the Net.

-Use of the Net: The user is able to use a wide variety of instruments and services and can use the Net with enough security. He/she is also aware of the dangers characterizing this technology. From the relational point of view, he/she establishes a relationship with the Internet defined as "man-machine-man" meaning the Net will be conceived as a means of communication.

-Abuse of the Net: The user begins to select more satisfying applications of the Net. He/she increases their time spent online and the frequency of connection to the Net. From a relational point of view, he establishes a kind of relationship defined as "man-machine-man." The user begins to use the Net to meet people online, even though he may not be aware of it.

-Net Addiction: The user limits the use of the Net by dedicating his/her time to a few applications and services (particularly chat and MUDs). From the relational point of view, he establishes a relationship defined as "man-machine." Even though the user communicates with other people, these relationships will be conceived as objects of pleasure.

Use of the Internet in relation to addiction has been confirmed in numerous international studies. Addicted users tend to prefer game sites, chat and beyond that, sites containing pornographic material (Morahan-Martin & Schumacher, 2000; Chou & Hsiao, 2000; Leung, 2004; Simkova & Cincera, 2004). Moreover, the increase in time spent online, one of the other aspects that underlies the model, is one of the evaluation criteria formulated by Young to make a diagnosis of IA (Young, 1998).

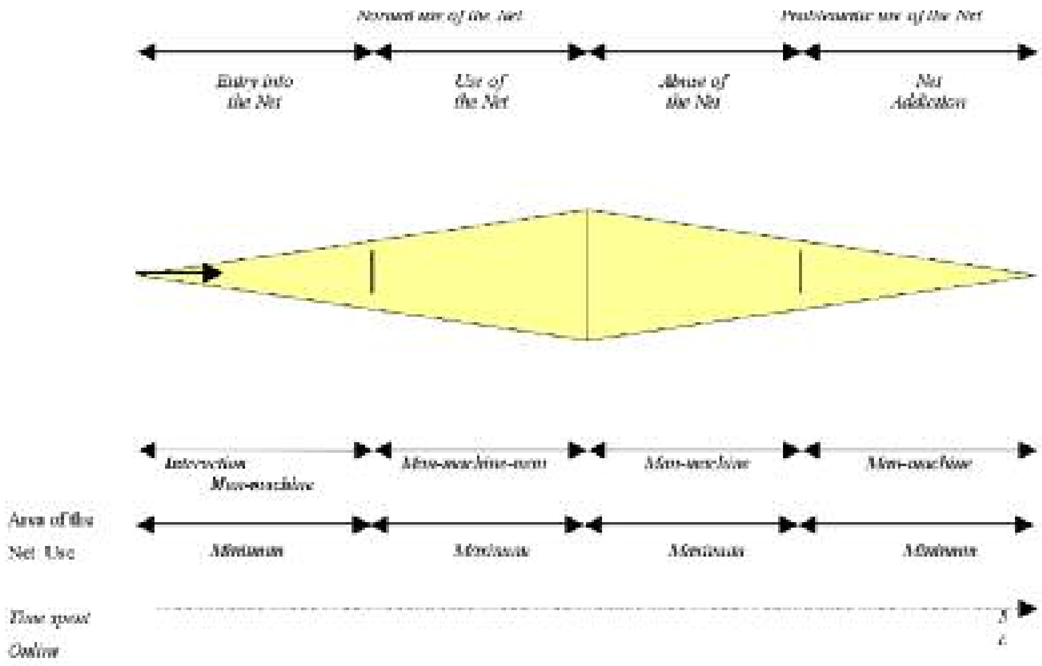

Figure 2. Symmetrical pattern (Cantelmi & Talli, 2007)

Grohol (1999) believes that subjects suffering from this disorder are, most frequently, new users of the Net. They are not accustomed yet to the new technological environment and remain "enchanted." However, even those who have been using the Net for longer periods of time could develop the disorder, but only after discovering a new, particularly attractive application. Both new and old users have the capacity to reach stadium III, the stadium of balance, soon or later (see figure 3).

MOTIVATIONS

Observations on IA often define an Internet addicted user as a subject who seeks comfort in the Net to avoid thinking about his/her problems. In reality, the subjects choose to connect to the Net for different reasons. The same applications (chat, MUD, etc.) could have different meanings and consequences for the subject. Cantelmi and Talli (2007) hypothesize two different types of Net addicts–Net addicts for escape and Net addicts for action. The Net addict for escape represents the real "stereotype" of an In-

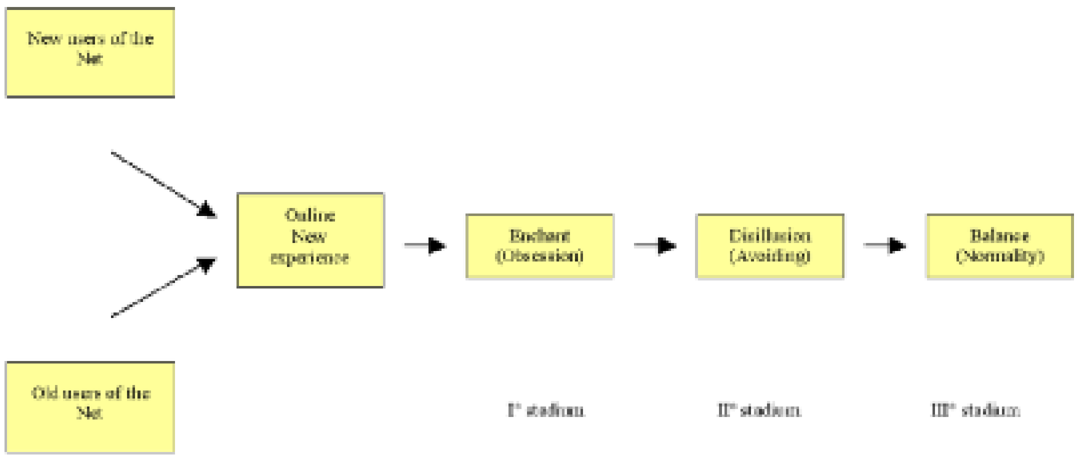

Figure 3. Grohol' s pattern of the Pathological Internet Use (Grohol, 1999).

ternet addict, since they use the Net mainly to escape from his/her depressive life. His/her real life is characterized by objective problems and by a strong sense of impotence and social non-involvement. This type of user logs onto the Net exclusively to escape from the real sorrow of their life, without expectations for any successful personal change. In this case, the Net is like an analgesic. They do not believe they can change their psychological condition–they just needs to use the Net for excitement and to dull their senses more and more. In those cases of intense intoxication the Net addict for escape replaces his/her real life with a virtual dimension, so that he/she will be facing striking dissociative and/or autistic psychopathological phenomena. Instead, the Net addict for action uses the Internet to achieve an objective that goes beyond the need to seek excitement. Cyberspace represents a large possibility of stimuli for them, but above all, the ideal space to make their high expectations become concrete. Action fields vary from online social relationships that can extend beyond the virtual dimension, to online gambling–considered by some to be a great occasion to make money. In those cases of intense intoxication the Net addict for action becomes so ambitious and far removed from reality that their actions can border on mania. It is known that the beginning of addiction, induced both by substances and behaviors, is caused by several factors. These factors do not come from the same situation, but they could come from several factors whose interaction can generate disorder.

Addiction = Inducing factors + triggering factors + perpetuating factors

Both the Net addict for escape and the Net addict for action uses the Net for excitement. But while the first addict uses it to escape from problems, the second type uses the Net to achieve success or make a change in their life. According to the aetiological sequence of the addiction, it is necessary to specify that the real target of online use is basically taking action online and not the excitement itself. Concerning the predisposition to IA, we have to consider a different psychological situation depending on the type of IA being discussed. In the case of IA for escape, people with more depressive aspects to their personalities and/or a tendency toward social difficulties would be more likely to develop the syndrome. On the other hand, in the case of IA for action, more vulnerable personalities would be those characterized by personal disorders (narcissism, obsession, etc.) and/or depressive (compensated) or maniacal aspects. However, it is important to note that subjects can use every online service for both escaping and for seeking success. Graphically, IA can be represented as a continuum that begins with the addiction for escape and arrives at the addiction for action (see figure 4).

Such a pattern can also integrate a transactional analysis (TA). The authors distinguished four fundamental attitudes or positions concerning how an addicted user perceives himself/herself, his/her surrounding reality and the virtuality of the Net (see table 3). For every position, it is possible to define the principal conditions in the life of the

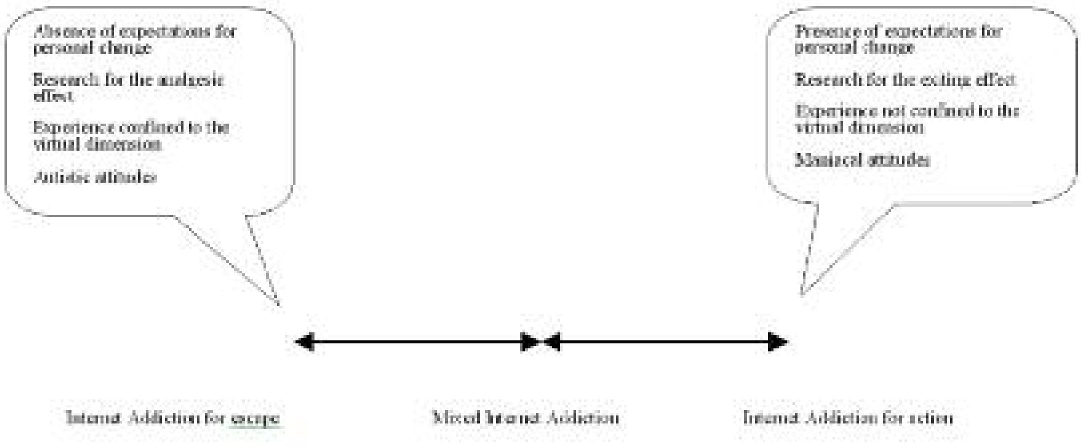

Figure 4. Continuum of the Net addiction.

subject, and their probable type of use of the Net (Net addict for escape or the Net addict for action).

From IRCs to Metaworlds

More than once it has been stated that not all Net applications present the same potentiality to create addiction, since each one implies the beginning of different psychological mechanisms. According to a well-known study carried out by Young (1997), addicted users spent longer amounts of time in synchronic communication environments like chats (35%) and MUDs (28%). Therefore, we assume that the same synchronic communication induces such gratification that it triggers even more active behavior from the user. Moreover, we can distinguish other additive characteristics connected to these particular resources.

For example, MUDs present outstanding elements of depersonalization, since they use a technology that minimizes playful contest by making identification of the player with the character easier (Cantelmi et al., 2000; Cantelmi & Giardina Grifo, 2002).

However, chats can represent an excellent modality for escaping from reality and everyday life. In chat rooms it is possible to interact with other users without being recognized and it is also possible to express personality with no fear of being judged. It is possible to take a fictitious identity and feel accepted and desirable to other users (Cantelmi & Giardina Grifo, 2001).

A less common phenomenon related to this type of communication is the so-called Zigarnick effect. It is a state of anxiety and accentuation of a thought linked to an interrupted conversation occurring in a chat setting online. The user disconnects from the Net, but continues to think about a dialogue that is still going on, even though they are not taking part in it (Martignago, 2001).

Many of the aspects underlined so far are developed by the so-called "metaworlds," such as Second Life, a popular example. What characterizes these virtual worlds is the chance to have an alter ego available–a digital representation of them self (an avatar)–that interacts in a world where other characters correspond to real people. Each encounter or conversation happening in Second Life, therefore, takes on the connotation of a real, interpersonal relationship. Differently from chats and MUDs, there is a strong element of human communication through the means of non-verbal language. It makes interactions more appropriate, if compared to real interactions, even though the avatars mediate the communicative exchange. In the metaworlds, we can find the same mechanisms of persuasion used in their advertising, whereas the most frequent expressions are "make your dreams come true" or "you will get what you desire."

Randazzo states, "Just like in the advertisement, the desire to be more than what we are is encouraged: more beauti-

Table 3
Net analysis (Cantelmi & Talli, 2007)

Perception of the reality (good – bad)	Perception of itself (good – bad)	Perception of the virtuality (good – bad)	Position
bad	bad	good	The subject uses the net to avoid to think about himself and the surrounding reality (autistic seclusion). Net addict for escape
bad	good	good	The subject uses the net to escape from a frustrating reality (gateway). Net addict for escape
good	bad	good	The subject uses the net to increase his/her self-esteem (self-respect) or as mediator of his/her relations with the reality. Net addict for escape.
good	good	good	The subject uses the Net in a specific way in order to increase his/her excitement level or to reach precise objectives. Net addict for action
bad / good	bad / good	bad	In this case the subject cannot depend on the Net.

ful, richer, stronger, more powerful. While in the advertisement they make promises in order to persuade people to buy an object, in Second Life they promise a different life" (2008).

The major risk with becoming more involved in Second Life or other metaworlds takes place when people choose the virtual world as option over the real world. To the user, the consistency of the metaworld compared to real life offers the certainty of a family pattern and a pattern closer to our stereotype. The wider range of possibilities offered by the parallel reality can also make it more attractive than the real world.

Cyber-Intoxication

Interactive spaces are not the only Net environments with irresistible and attractive characteristics, even though the majority of the cases of immoderate Internet use can be ascribed to them.

Among the most important new addictions already supported by the clinical case histories (most documented in the U.S.) are:

- Cybersex Addiction. The word "cybersex" concerns all activities with sexual features performed on the Net by using e-mail, IRC, CUSeeMe channels, etc. The typical user who engages in cybersex is a person who is afraid of a real physical relationship and who has difficulties being involved in affective relationships. However, it is possible to observe Internet abuse and addiction situations even in those subjects that have good affective and relational resources. In these cases, they develop an additional modality involving virtual sex use not because they are afraid of real sex, but because they adopt an attitude that, at the beginning, is playful. Some of them can keep this aspect under control, but some others get progressively involved, and this can result in compulsivity and the need to log on for hours and hours everyday.

- Compulsive Online Gambling. This disorder has already been recognized for a long time and is included in the mental disorders diagnostic manual. The chance to have access to virtual casinos or sites for gamblers from home enables the development of this compulsion and has a negative effect on relationships and finances in real life. It can also affect very young people.

- MUDs Addiction. As stated earlier, MUDs (Multi-users dungeon or Multi-user dimension) are interactive role-playing games, in which users can interact simultaneously. It consists of creating a fictional character with which the subject identifies and plays. The player can decide on physical and mental features of his/her alter ego, places they will visit, etc. Compared to traditional role-playing games, MUDs includes more aspects of depersonalization because the technology employed makes the playful context less evident and enables a major identification of the player with the virtual character.

-Cyber Relationship Addiction. Some subjects suffering from IA feel a strong need to establish amicable/affective relationships throughout e-mail, chat lines or newsgroup, to the detriment of their own real familial and social relationships. Since there is sometimes a lack of visual representation, people involved in chat can lie about their identity (concerning physical features, age, sex, job and status) in order to feel the euphoria of indefinite freedom. They can introduce themselves to other people and have the chance to fulfil their "ideal ego" in a virtual setting. In this way, they maintain a satisfactory virtual image of himself/herself, created among acquaintances and people regularly getting in touch, which remains confined to the limits of the Net. On one hand, the use of chats reproduces a relational and communicative context with the "other," and on the other hand, it implies the risk to deny or get in touch with the "other" in a partial or narcissistic way.

-Information Overloads Addiction. This kind of addiction, well known in work environments, is characterized by the exhausting research for any type of information, even trivia. The user does not distinguish between useful information and useless information. It is possible to search for information using an activity like web surfing (passing from one site to another) and/or surveys conducted on material placed in a database.

Means of Assessment

Many tests have been created to evaluate IA. Some of them include the Internet Addiction Questionnaire, Suler (1996), Davis Online Cognition Scale, Davis et al. (2002), Chen Internet Addiction Scale, Chen et al. 2003) and Internet Addiction Test, Young (1998). Young's is probably the most widely used worldwide (Talli et al., 1998).
In Italy Del Miglio, Gamba and Cantelmi (2001) proposed an instrument called Use Abuse Internet Addiction (UADI). This questionnaire was drawn up at "La Sapienza" University in Rome, and is the only Italian instrument applicable to the affected population. UADI is made of 75 items. It is possible to answer each item using the Likert scale, consisting of five levels (1=absolutely false; 2=rather false; 3=neither true or false; 4=enough true; 5=absolutely true).
The test shows five main dimensions:

- Compensatory escape (EVA): the tendency to escape from everyday difficulties through Internet use;

- Dissociation (DIS): the appearance of bizarre sensory experiences;

- Impact on real life (IMP): the appearance of consequences in the real life, change of habits, moods and social relationships;

- Experimentation (SPE): the tendency to use the Internet to experiment with parts of oneself and/or seek new emotions;

- Addiction (DIP): the appearance of signs of addiction, including progressive increase of time spent online, compulsivity and excessive involvement.

Cantelmi and Talli (2007) propose to examine the IA phenomenon in the most objective way possible, using software that overcomes the classical methodology of the “self-report” questionnaire. The developed software (IRP-AS) can operate in an unobtrusive way–this means that the user will be aware of it only when Internet use is possibly becoming problematic. In this particular case, the software will start up and warn the Net user about the dangers related to its abuse.

The software performs two different types of analyses:

- Quantitative analysis: Since the program can detect the actions of the user online (for example, in chats and MUDs) and the connection time, it can evaluate the level of involvement achieved by the user (if he/she abuses the Net and how much he/she depends on the Net) and some important indicators such as tolerance risk or dissociation risk (see table 4, next page).

- Qualitative analysis: The program displays the main contents explored during Web navigation (pornographic, political, ecological contents, etc.) and calculates the appearance frequency. In this way, for example, it is possible to understand whether a subject uses chat for friendship or sexual reasons (see figure 5).

In terms of use-abuse-addiction, the software calculates daily involvement (Cg) on the basis of some indicators, such as the frequency of daily use (Fg), basic motivation (M), if it is playful or working, daily time spent online (Tg), difference of time spent online in the last two weeks (Ts2 / Ts1) and the level of daily exposure (Eg). Particularly, the last indicator represents the trend of how much time the subject is connected to the Internet without interruption. The higher this value is, the higher the probability that the subject develops a dissociative symptomatology. The ratio Ts2 / Ts1 allows the evaluation of the tendency of the subject to progressively increase his/her time spent online (tolerance phenomenon).

$$Cg = (Fg \cdot Tg \cdot Eg / M) \cdot (Ts2 / Ts1)$$

Concerning the qualitative analysis, contents most frequently researched by users are counted and grouped into general categories such as violence, sex, etc. In this way, it is possible to integrate the results of the quantitative analysis with content information, so that it is possible to outline interests and needs that the Net satisfies for the subject.

This operation allows the understanding of whether a subject uses the chat for friendship or sexual reasons and whether his/her form of MUD addiction concerns role-playing with a sexual or violent content.

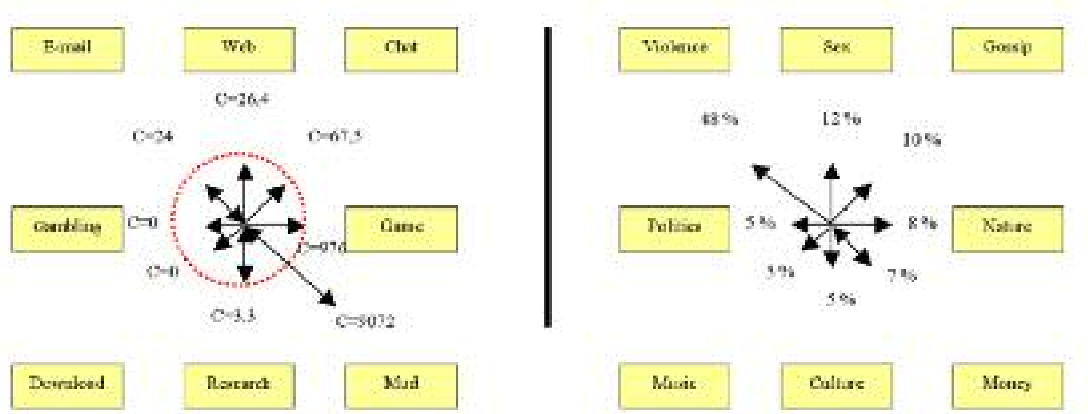

Figure 5. Examples of qualitative analysis (Cantelmi & Talli, 2007).

Table 4
Examples of quantitative analysis (Cantelmi & Talli, 2007)

Online Activity	Daily Use Frequency	Time spent online (minutes)	Ts2 / Ts1	Reason exposure 1 = <120' 2 = 121'-240' 3 = 241'-360' 4 = >360'	Motivation 1=Personal 2=Working	Involvement.
Chat	3	30	0,75	1	1	67,5
E-mail	2	12	1	1	1	24
Research	5	2	0,66	1	2	3,3
Gambling	0	0	0	1	1	0
Mud	6	420	1,2	3	1	9072
Download	0	0	1	1	1	0
Web	4	20	0,66	1	2	26,4
Game	2	244	1	2	1	976

Contents	Percentage
Violence	45
Sex	12
Gossip	10
Nature	8
Money	7
Culture	5
Music	5
Politics	5
Total	100

Level of involvement	Use of the Net	Tolerance Risk	Dissociation Risk	Diagnosis
Use	Generalized	No	No	MUD Internet Addict in the addiction phase
Abuse	Specific	Yes	Yes	MUD content is predominantly violent
Dependency				

What Kind of Treatment?

As Young already noted, finding the right treatment to this problem has been difficult. It has been even more difficult in a country like Italy. Many psychiatrists and psychotherapists are not qualified yet to handle IA and some others do not recognize its existence (Fata, 2000).
As a rule, the following treatments are prescribed:

- Self-help Groups: composed of people with the same problem, they share the same experiences in order to reacquire control over the Net.

- The Twelve Steps: this supports the personal and spiritual recovering of the individual through a method similar the method used for Alcoholics Anonymous.

- Therapeutic Counseling: counseling helps Net addicts become aware of their problem by encouraging psychological change.

- Individual Psychotherapy: it is suggested particularly if IA goes with the previous pathology. Patients become aware of the deepest parts of themselves and how they can change.

- Detoxification Strategies: useful to face up to and resolve problems, especially from the behavioral point of view.

Despite the scarcity of studies conducted on the abovementioned forms of treatment, Italy has been amontg the first of the European countries to experiment with a new form of online psychotherapy aimed at treating cases of Net Addiction. The service, accessible through the site www.psychoinside.it, offers free counseling and therapeutic supports (Cantelmi, Putti & Talli, 2001).

Conclusions

In the last 10-15 years, few phenomena underwent such considerable growth as the Internet. Few technological innovations have been able to, in such a short amount of time, enter into common use and influence everyday life so much. "The technical evolution of the information mean is so fast that the analysis of a phenomenon will be completed when the phenomenon readapts itself or gets transformed into another" (Gaston, 2005).

Nonetheless, in this review provided references to help determine what is and what is not IA. Therefore, we gathered a large amount of information and data, disconcerting for its proportions, like the unquestionable pathological potential of the Net. Even though completed studies are not yet able discern a cause/effect relationship, the appearance of specific symptoms concerning intensive use of the Net shows that we cannot deny that the Net represents a strong catalyst for preexisting psychopathologies. It embodies an ideal place where it is possible to express the worst and the most pathological aspects of oneself.

It has been verified that an important psychopathologic risk indicator is represented by long amounts of time spent online. The greater the amount of time spent on the Net, the higher the probability is of developing one of the various forms of addiction. On the basis of our experience, the user should not exceed five to six hours per day, only for work or study reasons (Cantelmi & Carpino, 2005).

Among the new contributions we presented, it is important to mention IRP-AS, software for the evaluation of the syndrome on the basis of time spent online. This instrument could represent a large amount of support for preventing new addiction cases. Similarly to vehicular accidents, instruments such as speed cameras can detect speed to prevent incidents.

In order to take advantage of the considerable capacity of the Net without risk of becoming "trapped," it is necessary to know the instrument adequately, be aware of the factors encouraging telematic overdose and recognize the signs warning us we are abusing it.

We discussed the Second Life phenomenon, in which there are six million inhabitants. Recently, designers have implemented new software that allows voice communicate between Avatars who share the same virtual dimension. A new interactivity system will surely follow among users and the virtual world, such as tactile instruments or instruments for the perception of perfume. In the future, the monitor could be replaced by the use of specific glasses already used in the most sophisticated Virtual Reality games and by military pilots during flight simulations. The instinctive movement of the eyeball would be replaced by the movement performed by a mouse, obtaining the three-dimensional illusion of moving and taking action in the virtual environment, as if the user were really in the observed world. In the next future, the current studis on the neurosciences could develop into the use of neuronal sensors. Researchers could be able to blend the holographic image of the virtual dimension with the cerebral image into a single vision. This already happens when we watch a movie and we become so absorbed in the scene that we may lose the outlines of the screen (Nattero & Barbadoro, 2007). In this case, the captivation of the Net would be equal with the perspectives that we could imagine…

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CYBERPROJECTS

IN THIS FEATURE, we will try to describe the characteristics of current cyberpsychology and rehabilitation research. In particular, CyberProjects aims at describing the leading research groups and projects, actually running around the world, with a special focus on European research.

Social Signal Processing: the use of computers for understanding social interactions

Social Signal Processing aims at developing artificial social intelligence, i.e. to make computers capable of sensing, interpreting and generating social signals

Social Signal Processing (SSP) is a new research domain, still in its pioneering phase, at the interface between engineering and human sciences. In simple terms, the goal of SSP is to develop artificial social intelligence, i.e. to make computers capable of sensing, interpreting and generating social signals. These are complex constellations of nonverbal behaviors through which humans convey relational attitudes like empathy, agreement, affiliation, dominance or conflict. The effectiveness of social signals is evident in the scene discussed below. When asked to describe this scene, around half of the interviewed subjects provide the correct answer, i.e. the individuals form a couple and they are fighting. Such accuracy is possible even if only limited information is available–the interaction is intense (the mouths are wide open and the hands of the woman are far from being relaxed) and the portrayed individuals have a strong relationship (the interpersonal distance can be so small only when people are close friends or belong to the same family).

To explore this new field, recently the European Union funded the "Social Signal Processing Network" (SSPNet) Network of Excellence under work programme topic ICT-2007.2.2 of the European Community's Seventh Framework Programme (FP7/2007-2013), under grant agreement no. 231287. The project, running from February 1, 2009 for 60 months, is coordinated by Alessandro Vinciarelli (IDIAP, active in IM2.MCA) and Maja Pantic (Imperial College london).

The SSPNet will try to "teach" computers socially adept behaviors by sensing, interpreting and generating behavioral clues. To address an intrinsically interdisciplinary problem like Social Signal Processing, SSPNet includes not only engineering groups with expertise in analysis and synthesis of human behaviors and social interactions, but also psychologists and social scientists working on cognitive modeling of human behavior.

The engineering side is composed of IDIAP Research Institute (CH), Imperial College (UK), University of Edinburgh (UK), Technical University of Delft (Nl), CNRS (f), University of Twente (Nl) and DfkI (D). The human sciences side is composed of University of Geneva (Ch), University of Roma Tre (I) and Queen's University Belfast (UK). The members of the consortium are convinced that SSP must be the result of a tight collaboration between human science and engineering researchers. For this reason, they will try to establish a new scientific domain where research is done in a different, and truly multidisciplinary manner. In this perspective, both human science and engineering researchers are keen to change their way of working.

For more information visit http://sspnet.eu/.

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Istituto Auxologico Italiano

CYBERFOCUS

New technologies are developing at a rapid pace. To help you stay abreast of the latest trends in advanced technologies and healthcare, this feature showcases upcoming, 2009- 2010 events, which will provide you with the opportunity to connect with leading experts worldwide and remain on the cutting edge of the most recent developments.

The CyberFocus column welcomes your contributions. To supply relevant information for this feature, please send an e-mail to: office@vrphobia.eu.
CyberPsychology & CyberTherapy 15
June 13 - 15, 2010
Seoul, Korea
www.interactivemediainstitute.com

The Journal of CyberTherapy & Rehabilitation is the official journal of the CyberTherapy Conference. The 15th Annual International CyberTherapy Conference (CT15) brings together researchers, clinicians, policy makers and funding agencies to share and discuss advancements in the growing discipline of CyberTherapy & Rehabilitation, which includes training, education, prevention, rehabilitation, and therapy. The focus of this year's conference is two-fold–first, "Technologies as Enabling Tools" will explore the use of advanced technologies in diagnosis, assessment and prevention of mental and physical disorders. In addition, attention will be drawn to the role of interactive media in training, education, rehabilitation and therapeutic interventions. Secondly, CT15 will investigate the "Impact of New Technologies" and how they are influencing behavior and society through cyberadvertising, cyberfashion and cyberstalking, among others. Technologies featured at the conference include VR simulations, video games, telehealth, the Internet, robotics, brain-computer interfaces, and non-invasive physiological monitoring devices. Conference attendees have the opportunity to play a role in designing the future of mental healthcare. CT15 features interactive exhibits at the Cyberarium allowing participants to experience the technologies firsthand as well as the opportunity to display their exhibits in a forum-type setting.

2009 Conferences

PRESENCE 2009: The 12th Annual International Workshop on Presence
November 11 - 13
Los Angeles, California, USA
http://www.temple.edu/ispr/conference/

ABCT 2009
November 19 - 22
New York City, New York, USA
http://www.abct.org/conv2009/

2010 Conferences

SPIE Photonics West
January 23 - 28
San Francisco, California, USA
http://spie.org/x1375.xml

DigitalWorld 2010
February 10 - 15
St. Maarten, Netherlands Antilles
www.iaria.org/conferences2010/DigitalWorld10.html

6th Annual Update Symposium Series on Clinical Neurology and Neurophysiology
February 15 - 16
Tel Aviv, Israel
http://isas.co.il/

IASTED International Conference on Artificial Intelligence and Applications
February 15 - 17
Innsbruck, Austria
http://www.iasted.org/conferences/

RAVE 2010 - Real Actions in Virtual Environments
March 3
Barcelona, Spain
www.raveconference.com

The World of Health IT Conference & Exhibition
March 15 - 18
Barcelona, Spain
http://www.worldofhealthit.org/

IEEE VR 2010
March 20 - 24
Waltham, Massachusetts, USA
http://conferences.computer.org/vr/2010/

Applied Psychophysiology & Biofeedback 2010
March 24 - 27
San Diego, California, USA
http://www.aapb.org/

SPIE Defense, Security, and Sensing
April 5 - 9
Orlando, Florida, USA
http://spie.org/x1375.xml

Society of Behavioral Medicine: 2010
April 7 - 10
Seattle, WA
http://www.sbm.org/meetings/

Laval Virtual 2010: 12th Virtual Reality International Conference
April 7 - 11
Laval, France
http://www.laval-virtual.org/

The 7th Annual World Health Care Congress
April 12 - 14
Washington D.C., USA
http://www.worldcongress.com/events/

Med-e-Tel
April 14 - 16
Luxembourg
http://www.medetel.lu/index.php

19th International World Wide Web Conference: WWW2010
April 26 - 30
Raleigh, North Carolina, USA
http://www2010.org/www/

The 5th International Conference on Interactive Mobile and Computer Aided Learning
Date - TBA
Amman, Jordan
http://www.imcl-conference.org/

American Telemedicine Association 2010: 15th Annual International Meeting and Exposition
May 16 - 18
San Antonio, Texas, USA
http://www.americantelemed.org/i4a/pages/index.cfm?pageID=3629

The 6th Annual World Health Care Congress – Europe
May 19 - 20
Brussels, Belgium
http://www.worldcongress.com/events/HR10015/

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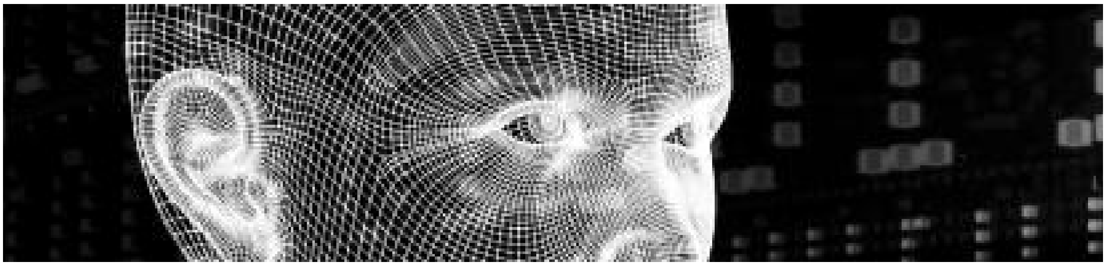
8th ICDVRAT with ArtAbilitation
August 31 - September 2
Valparaiso, Chile
http://www.icdvrat.rdg.ac.uk/

40th European Association for Behavioural and Cognitive Therapies Annual Conference
October 7 - 10
Milan, Italy
http://www.eabct2010-milan.it/

ABCT 2010
November 18 - 21
San Francisco, California, USA
http://www.abct.org/dMembers/?m=mMembers&fa=Convention


CyberPsychology
& Behavior
The Impact of the Internet, Multimedia, and
Virtual Reality on Behavior and Society
Coming in February 2010
Special Issue on PTSD
www.liebertpub.com/cpb
Mary Ann Liebert, Inc. publishers



FOR AUTHORS

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